GENERAL MOTORS

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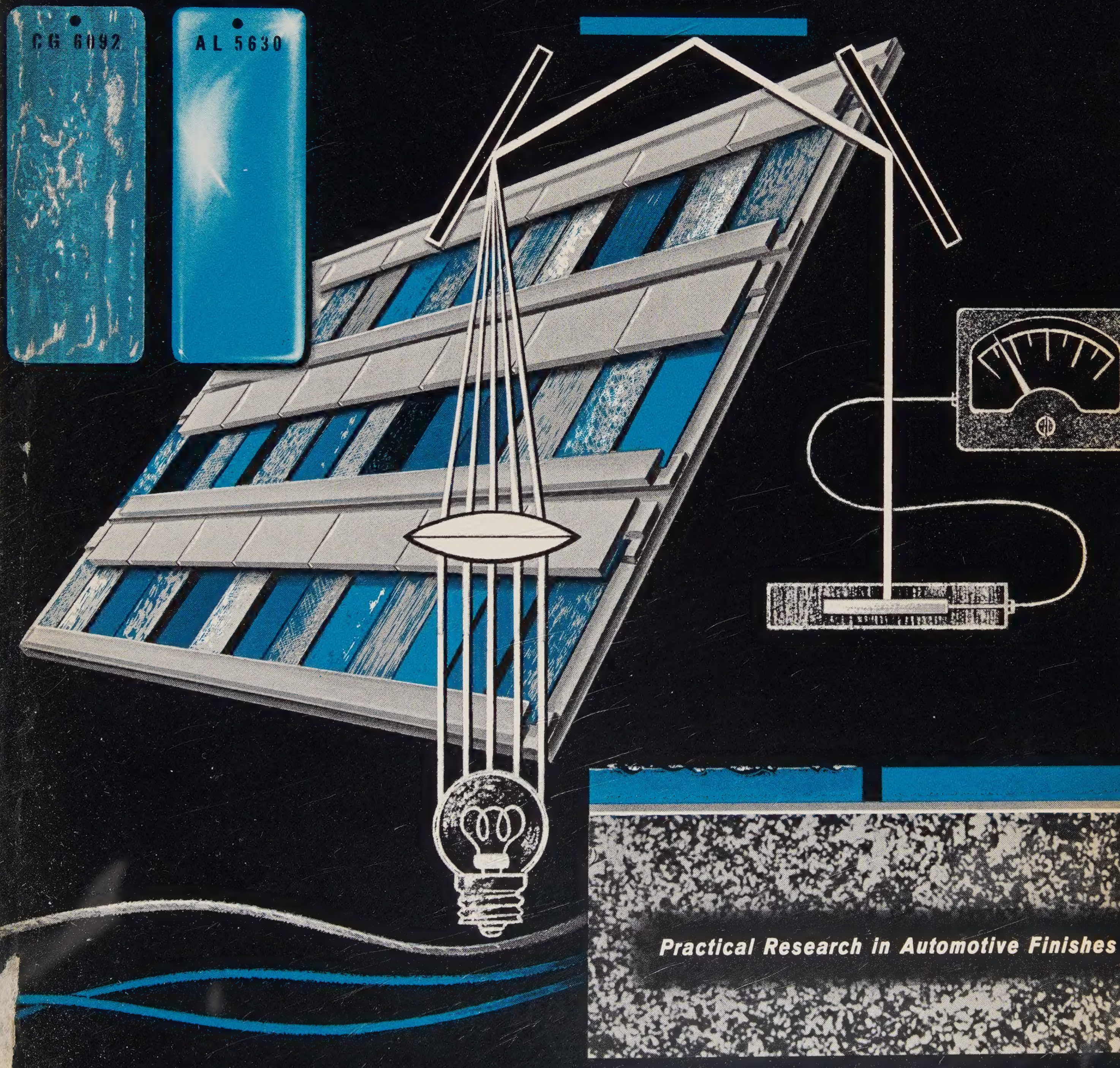
JOURNAL

for educators in the fields of engineering and allied sciences



Practical Research in Automotive Finishes

On Successful Innovation and a Growing Economy

Enterprise is the word we often use to describe what our economy is all about. A "free enterprise system" is a system that encourages and rewards "enterprising" people—people who are not content to remain static. They welcome and initiate innovation and worthwhile change rather than resist them. The essential quality of a dynamic economy is change—constructive change. This is the essence of enterprise.

The most dramatic instances of change in our economic history are associated with the great innovations, such as the development of the railroads in the late 19th Century, the growth of the automobile and the electric power industry in the first two decades of this century and, more recently, the expansion of all branches of chemistry and the growth of the air transport and the electronics industries. Such innovations have opened up almost unbelievable opportunities for investment, for employment, for economic growth, and for improvement of our living standard. They were made possible by the individual efforts of many enterprisers.

Equally important although less dramatic are the almost daily changes made in products, in manufacturing processes, and in distribution methods. In the aggregate these constitute a continuing and vital force in assuring growth.

But why is change characteristic of America? In my opinion, it is a direct result of the way we have organized ourselves to carry on the business of living. At the very heart of this system are two powerful forces—the hope of profit and the discipline of competitive markets.

The hope of profit is the mainspring of constructive change. Competition is the spur that transforms new ideas into new products at the lowest possible price. Whether the first step in a series of changes is big or little, the pressure of competition results in their rapid spread to other firms in an industry, thus opening up additional areas of investment opportunity and creating more jobs.

These processes are chain reactions whose tremendous energy works for the good of the economy as a whole. It is the broadening out of these contributions throughout industry that is as important as the innovations that stimulated them.

No other system has so successfully turned each man's natural interest in his own advancement to the productive serving of the needs of society. No other system holds out such great potential rewards to the successful innovator. It encourages enlightened self-interest in its most useful form.

Using the phrase, "potential rewards to the successful innovator," brings me to a fundamental point: our dynamic growth would not have been possible without risk to the individual enterprise. The process of change is the process of risk-taking. Before any new idea, transformed into a product or service, can find its way to the market place, an investment of time, effort, and money is required. Often the investment in all three is very large. The test of whether a change is good is the acceptance of that change in the market. For every product which finds acceptance, many are offered and cast aside.

Competition insures the spread of change. But it is profit—representing potential reward to the successful innovator—that leads to the risk-taking which makes the process of change and growth possible. It is the responsibility of management to take risks in the hope of profit by bringing new products and new services to the customer.

The growth of our economy has proven how well management has fulfilled its responsibility. Our great potential for future growth can only be realized if management continues to look ahead and continues to take risks.

This is the contribution which business can and must make to insure dynamic growth. It is, moreover, a contribution which represents a challenge to all future members of the management team—persons who today may be just starting their careers or who may yet be students in the nation's colleges and universities.

Frederic G. Donner

Frederic G. Donner,
Chairman

GENERAL MOTORS
ENGINEERING
JOURNAL

THE COVER

Progress in finishes for the exterior metal surfaces of automobiles is represented in this issue's cover designed by artist Richard P. Renius. An important new development is acrylic lacquer which is more durable and retains its high gloss finish at least three times longer than conventional lacquers.

The development and testing which preceded the introduction of acrylic lacquer are suggested by the components shown. Illustrated in a schematic way is an instrument called the gloss meter, which measures the reflective characteristics of a painted surface. The exposure rack in the background represents the outdoor testing of hundreds of painted metal samples.

The back cover symbolizes the advancements in processing techniques which also have been a part of the development of automotive finishes.

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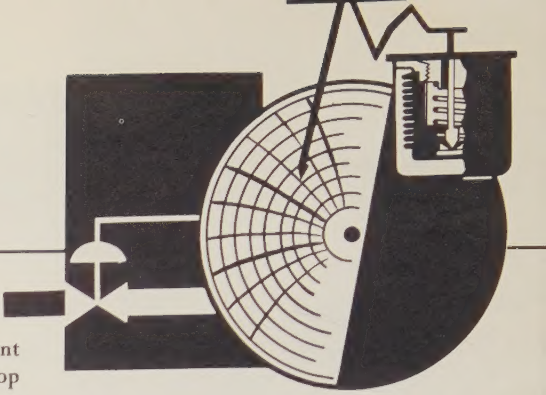
A Qualitative Analysis of Automatic Control Functions



The widespread use of closed loop, automatic control in industry is a relatively recent innovation. Before World War II most plant instrumentation consisted of open-loop indicators installed primarily for guiding operators in the manual control of a manufacturing process. During the War, demands for increased production and better quality control brought about the rapid growth of continuous-type operations requiring automatic machinery and handling methods. Measuring and indicating instrumentation soon were integrated into complicated control systems, which in many cases encompassed the entire plant. Since then, automatic control devices have found their way into practically every phase of manufacturing. The successful application of automatic controllers requires a complete understanding of certain inherent characteristics associated with each type of controller. A mathematical approach to automatic control theory is one way to achieve such an understanding. Another approach is through qualitative analysis of the fundamental modes of automatic control together with the use of simple analogies. The automotive engine cooling system thermostat represents an ideal device to illustrate the basic concepts involved in the application of automatic controls.

When the recently graduated engineer enters industry he often is confronted with problems involving the practical application of automatic controllers, also known as regulators, servomechanisms, and governors. The diversity of design, the variety of operational mechanics, and the ambiguity of nomenclature tend to confuse the engineer in understanding the theory of operation of the various type of controllers. Fortunately, the fundamental concepts of automatic control apply whether the control system is hydraulic, mechanical, pneumatic, or electrical.

A purely mathematical approach to the study of automatic control system theory and operation is certainly most desirable from the standpoint of accuracy. The mathematics involved, however, presents a bewildering assortment of exponential and trigonometric functions. In actual practice, the engineer usually does not have the time to work through and digest the mathematics involved in solving a current control application problem.

In place of the mathematical approach, the theory of automatic control can be studied from the mechanical viewpoint. The fundamental concepts of automatic controls can be examined qualitatively and non-mathematically by using simple analogies. In the discussion which follows, this approach will be used. Each of the basic automatic control functions and their characteristics will be examined as they apply to an automotive engine cooling system thermostat. The principles derived using this analogy can be applied to other systems. The mechanical configurations used to illustrate basic concepts perhaps will be unconventional. The illustrations, however, will serve to convey the operating principles. It is recognized that the arrangement probably would differ in actual practice.

Each field of engineering using automatic controls originally adopted its own control nomenclature. Since this led to considerable confusion, automatic control terminology has been standardized by the American Society of Mechanical Engineers[1]. In this paper, standard terms will be used where they apply and will be italicized.

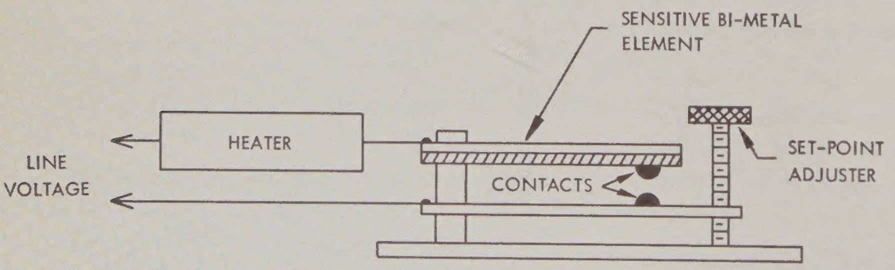


Fig. 1—The thermo-switch used in the household hand iron is an example of the *two-position* type of controller. When voltage is applied, the heater is energized through the contacts. As the temperature reaches the desired setting the bimetal strip bends up and opens the contacts. The heater then cools until the contacts close. Voltage is again applied to the heater. The cycle is repeated as long as line voltage is connected. The *set point* is selected by adjusting the screw. The main disadvantage of the two-position controller is that the temperature never remains constant, but oscillates continually above and below the desired setting.

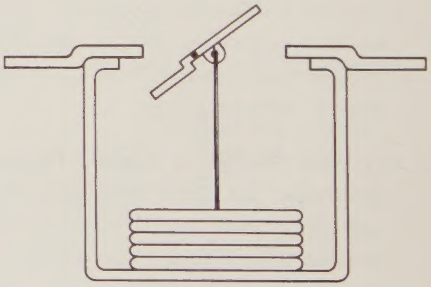


Fig. 2—The automotive engine cooling system thermostat is an example of a *proportional-position* type of controller. The thermostat consists of a liquid-filled bellows connected to a butterfly valve. Temperature changes of the liquid expand or contract the bellows, actuating the valve. The proportional-position type of controller differs from the two-position type in that its action occurs over a range of temperatures, instead of at a fixed point.

By RUSSELL V. FISHER
GM Research Laboratories

One approach to the basic concepts of automatic control systems

Proportional-Position Controller Eliminates Continuous Cycling of Control Point

The simplest and most widely used controller device is the *two-position*, or on-off, controller (Fig. 1). In this type of controller, a final control element is moved from one of two fixed positions to the other. Examples of this type of controller are found in household appliances, such as hand irons, heating systems, and water heaters. Simple two-position controllers also are used extensively in non-critical industrial processes. The two-position controller is perfectly satisfactory where close control is unnecessary and where continuous *cycling* of *control point* can be tolerated. (The control point is the value of the controlled variable which at any instant the controller operates to maintain.)

In applications where control requirements are more stringent, the *proportional-position* type of controller is used. An example of such a device is the automotive engine thermostat (Fig. 2).

The proportional-position type controller, when applied to the automotive engine thermostat, differs from the two-position type in that its action occurs over a range of temperatures instead of at a fixed point. Every temperature in the range has a definite corresponding valve position. (The valve represents the final control element.) An incremental change in temperature results in an incremental change in valve position. The valve motion usually is made proportional to the temperature change.

In many applications, the proportional-position controller has the ability to damp out temperature cycling. The heat transfer characteristics of each particular system where the controller is applied determine the proportionality ratio necessary to eliminate temperature cycling. This ratio is fixed in a standardized design, such as the engine thermostat, but generally is made adjustable in industrial instruments.

An automotive engine cooling system (Fig. 3-left) can serve to illustrate the basic fundamentals involved in the application of a proportional-position type controller. In turn, the dynamic behavior of this system, with a thermostat *set point* of 180°F, can be presented in graphical form (Fig. 3-right) to illustrate further the fundamental concepts. For the purpose of explanation, assume that the valve of the thermostat begins to open at 170°F, is half way open at 180°F, and is fully open at 190°F. The 20°F temperature range is called the *proportional band*, or throttling range. (The proportional band represents the range of values of the controlled variable which corresponds to the full operating range of the final control element.) Also assume, for the sake of simplicity, that normal engine operation requires a half-open valve to maintain a temperature of 180°F.

Proportional control will do a satisfactory job of maintaining the water temperature at 180°F only as long as normal engine loading is maintained. If the engine load is increased, such as when a car climbs a hill, more heat will be added to the water, raising its temperature. The thermostat valve, in turn, will open further allowing more water to flow. As a result, the temperature is no longer at the desired setting of 180°F, but is at some new equilibrium point above 180°F. If a 3/4-open valve is required to reach equilibrium, the new control point will be 185°F. The reverse situation would occur if the engine load decreased significantly. What results, therefore, is a difference between the control point and the value of the controlled variable, which corresponds to the desired setting. This undesirable effect is called *offset*, or droop, and is always present in proportional-position controllers.

Proportional-position control, then, represents a radical improvement over two-position control, because it eliminates continuous cycling. It has a disadvantage, however, in that offset results from load changes and the controlled variable cannot be held at a constant value. The degree of offset depends on the width of the proportional band and the magnitude of load variations.

Reset Action Gives Additional Response to Controllers

In many applications where a wide proportional band is necessary, and ex-

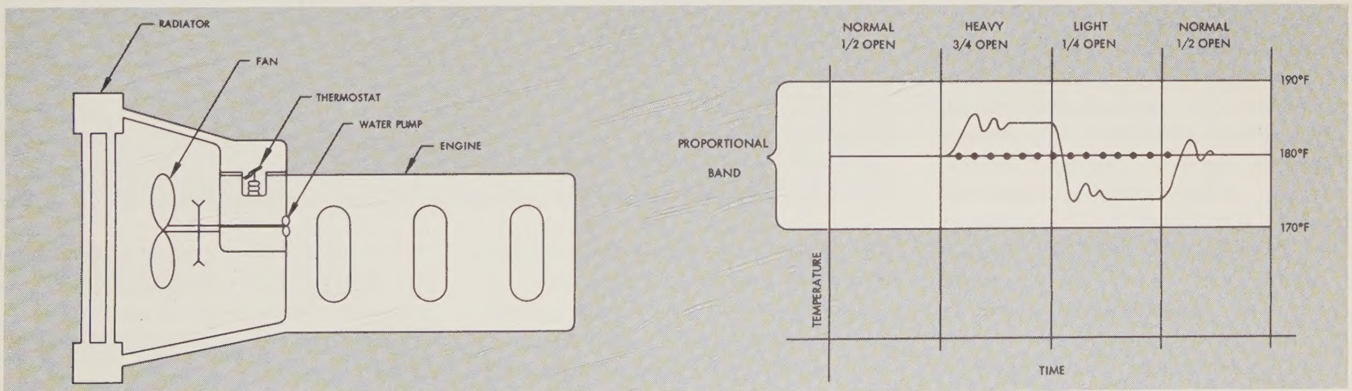


Fig. 3—The automotive engine cooling system (left) contains all the basic elements of any controlled process. Heat energy is generated in the combustion chambers. Water circulating in the jackets carries the heat to the radiator where it is then dissipated to the air. The thermostat, which is a proportional-position type of controller, regulates the flow of water as a function of temperature. If it is desired to maintain the water temperature at 180°F, the proportional-position type of thermostat will do so, but only as long as normal engine loading is maintained. When load changes occur the actual temperature will deviate from the desired value (right). This effect is called *offset*, and is always present in proportional-position controllers. The degree of offset depends on the width of the proportional band and the magnitude of load variations.

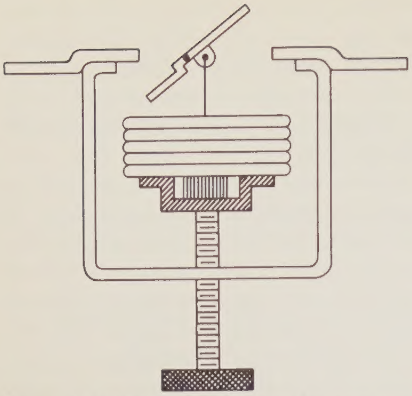


Fig. 4—Offset in proportional-position type controllers can be eliminated by an additional controller response known as *reset action.* The thermostat shown here has been modified to include manual reset, achieved by the addition of an adjustable knob to control bellows action and, in turn, increase or decrease the flow of water. When offset occurs due to load changes, the original set point temperature which the thermostat is to maintain can be obtained again by turning the knob to control the flow of water. Manual reset is acceptable where load changes are insignificant.

cessive load changes are prevalent, a modified version of the proportional controller is used to obtain satisfactory results. This additional controller response is known as *reset action*, or floating control. It also is referred to as *integral action.*

Reset action can be demonstrated by again referring to an automotive engine cooling system. This time, however, assume that a modified thermostat (Fig. 4) having a manually adjustable knob to control bellows action is installed in the engine. If the engine load is increased as before, the control point will deviate above 180°F, resulting in an offset. Assume, however, that when this occurs an operator manually adjusts the knob on the thermostat to open the valve wider and allow more water to flow, thereby reducing the temperature. Eventually, the original set point of 180°F would again be obtained. Offset would be eliminated until another load change occurred, at which time the reset action procedure would be repeated. The reset feature, therefore, serves to shift the proportional band to compensate for load changes (Fig. 5).

Manual reset is acceptable where load changes are insignificant or where an operator is available to perform the readjustment. Automatic reset, however, is more desirable.

The cooling system thermostat can be used again to illustrate the concept of automatic reset action. In this case, an electro-mechanical type of automatic reset is installed on the thermostat (Fig. 6) and the speed of reset is fixed. In modern controllers, the design is usually such that the speed of reset is proportional to the deviation. In addition, an adjustment is provided to vary the *reset rate* for a given deviation. The instrument is then tunable to almost any process requiring automatic control. The standard term used to describe this combined controller function is *proportional plus reset action.*

Proportional plus reset action is not a cure-all for every problem in automatic control. Its action must be slow enough to maintain stability. As a result, offset is eliminated only after it occurs. This operating condition is sometimes unacceptable. Also, if load changes occur frequently reset might never complete its action. In this case, proportional plus reset action would be practically useless.

Rate Action Stabilizes Control Systems

Another control function, known as *rate action*, is used to stabilize an unwieldly control system. Rate action, also referred to as derivative response, is a continuous linear relation between the rate of change of the controlled variable and the position of the final control element. Rate action can be used in conjunction with proportional-position or with proportional-position plus reset.

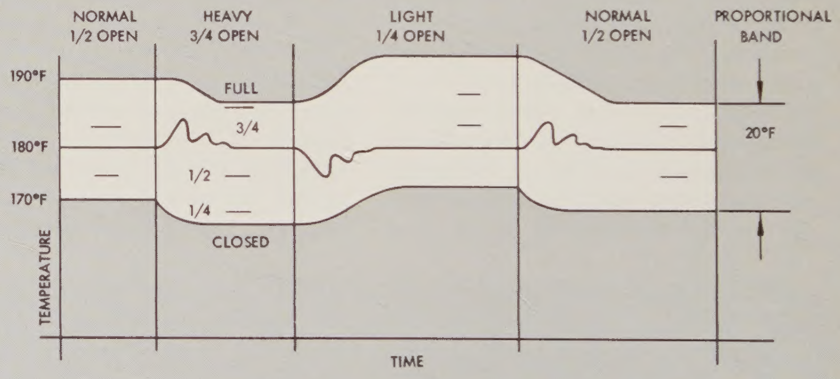


Fig. 5—When a controller has reset action, the proportional band floats with reset as load changes occur, thus returning the temperature to the set point.

If the automotive engine cooling system thermostat is modified to include rate action (Fig. 7), the valve motion is affected by the expansion and contraction of both the bellows and a temperature-sensitive link. An increase in engine load will cause the valve to open wider than it would with proportional action alone. Corrective action, therefore, is amplified temporarily. When the rate of temperature change decreases to zero the insulated part of the link assumes the same dimensions as the uninsulated part, and rate action ceases. Rate response cannot anticipate a system upset, but does compute the magnitude of steady state offset from the initial deviation rate and applies a magnified amount of corrective action.

With the rate action form of control, temperature cycling is damped out considerably sooner than with proportional-position alone (Fig. 8). The width of the proportional band can be reduced in a given system, thereby minimizing the effect of offset. In fact, the use of rate action sometimes eliminates completely the need for reset action. Most commercially available controllers incorporating rate action usually provide an adjustment for selecting the degree of action necessary for the particular application.

Control Applications Are Varied

All controllers, except the two-position type, contain one or more of the previously described operating characteristics. This fact becomes apparent as experience is accumulated in practical control problems. A few areas in which such problems would occur are:

- Integrated control of an automatic manufacturing facility
- Automatic steering and speed control of a vehicle

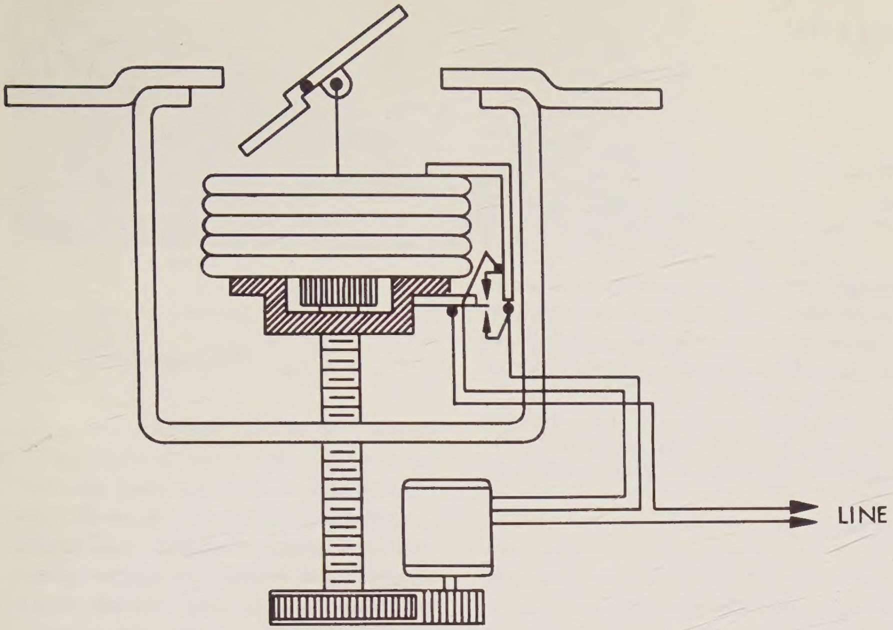


Fig. 6—The thermostat shown here has been modified to include an electro-mechanical type of automatic reset. A reversible motor is used to position the bellows assembly. The motor is energized by a single pole, double-throw contact mounted on the assembly. Whenever the temperature deviates from 180°F, one of the contacts is made causing the motor to move the bellows assembly and the valve. The temperature will slowly return to the set point. The direction of motion is determined by the switch position.

- Temperature control of a building air conditioning system
- Guidance of a missile.

Summary

Proportional, reset, and rate functions each contribute a special ingredient to controllability of a process. Considerable discretion should be exercised in the selection of these features in a controller. The simplest control should be used if it does the job, since complex instruments add needless expense and complication.

If a process in which a variable is to be controlled has not been planned intelligently the most elaborate controller will not correct basic errors or provide satisfactory control. A complete re-design of the control system may be necessary in such a case.

The applications of automatic control devices are limited only by the imagination of the engineer.

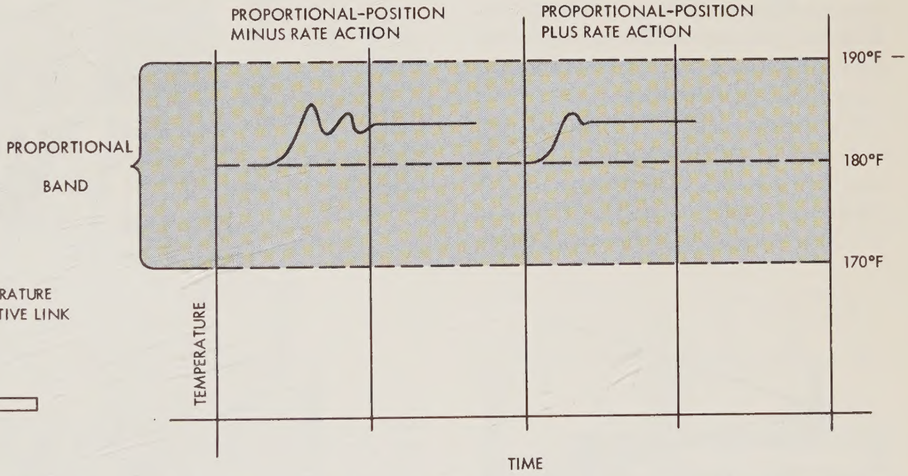


Fig. 8—The rate action control function can be used in conjunction with proportional-position controllers to reduce both the magnitude and duration of control point fluctuation after a process upset, as indicated in the graph. The width of the proportional ban can be reduced, thereby minimizing the effect of offset.

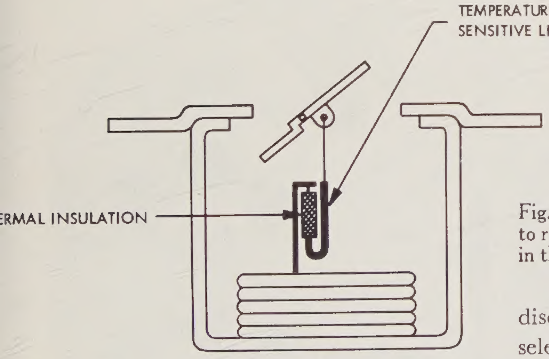


Fig. 7—*Rate action* can be illustrated by an automotive engine thermostat, as shown here. The temperature-sensitive hairpin link has a large thermal expansion coefficient. One side of the link is insulated. When a temperature change occurs, the link increases the valve motion beyond that resulting from bellows motion. The effect is dormant when the temperature is constant. The resulting additional valve motion, or rate action, is therefore a function of the rate of temperature change. Rate action effectively opposes short term temperature deviations by temporarily amplifying valve action.

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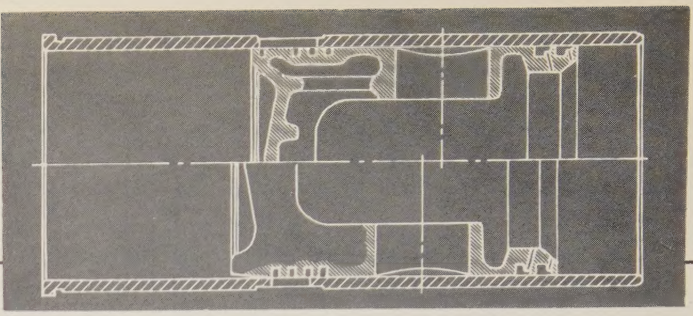
Improved Diesel Engine Provides Increased Fuel Economy



In the early days of the Diesel engine, fuel consumption was a relatively minor factor in engine design. Recently, however, the rising cost of Diesel fuel plus other operating cost factors have created a need for improved fuel economy in Diesel engines, especially so in the highway hauling industry. To meet this need, Detroit Diesel Engine Division engineers recently designed and developed a new engine series, the 71-E, based on the existing Series 71 Detroit Diesel engines. The newly developed engine has improved fuel economy, longer life, and equal power when compared with the standard Series 71 engine. In addition, the 71-E engine has a high degree of parts interchangeability with the Series 71 engine.

For many years Diesel engines had, in addition to higher thermal efficiency, a distinct fuel cost advantage over gasoline engine competition. This was due to a comparatively low demand for fuels in the Diesel distillation range plus a favorable fuel tax position.

As a result of this twofold fuel cost advantage, very little demand existed to improve Diesel engine fuel consumption. However, because the Diesel engine was heavy, slow, and lacked power in comparison to its gasoline counterpart, there was a demand, instead, for lighter, faster, and more powerful Diesel engines with improved durability. In the years immediately following World War II, most of the Diesel engine manufacturer's developmental work went into producing engines to meet this demand. As a result, engine speed and power were increased during this period, and the user experienced fewer and fewer breakdowns.

Engine fuel economy also was improved somewhat during this period. The increased average road speeds and vehicle weights made possible by the more powerful Diesel engines, however, more than offset the improved engine efficiency.

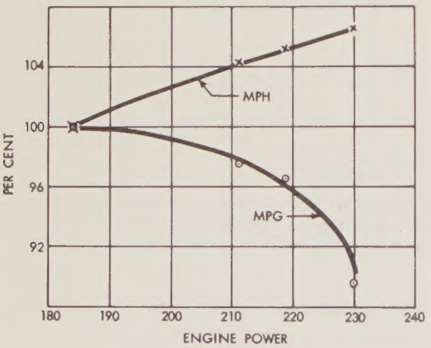


Fig. 1—The effect of Diesel engine power on highway truck economy involves both trip speed and fuel consumption. The graph shown here represents the results of a series of tests conducted in the early 1950's to determine the effect of increased engine horsepower on average trip speed and average fuel mileage. Increasing the engine power from 184 hp to 230 hp raised the trip speed six per cent and decreased the fuel mileage almost ten per cent. The data shown are for one particular vehicle weight under one given set of traffic, topographical, and weather conditions.

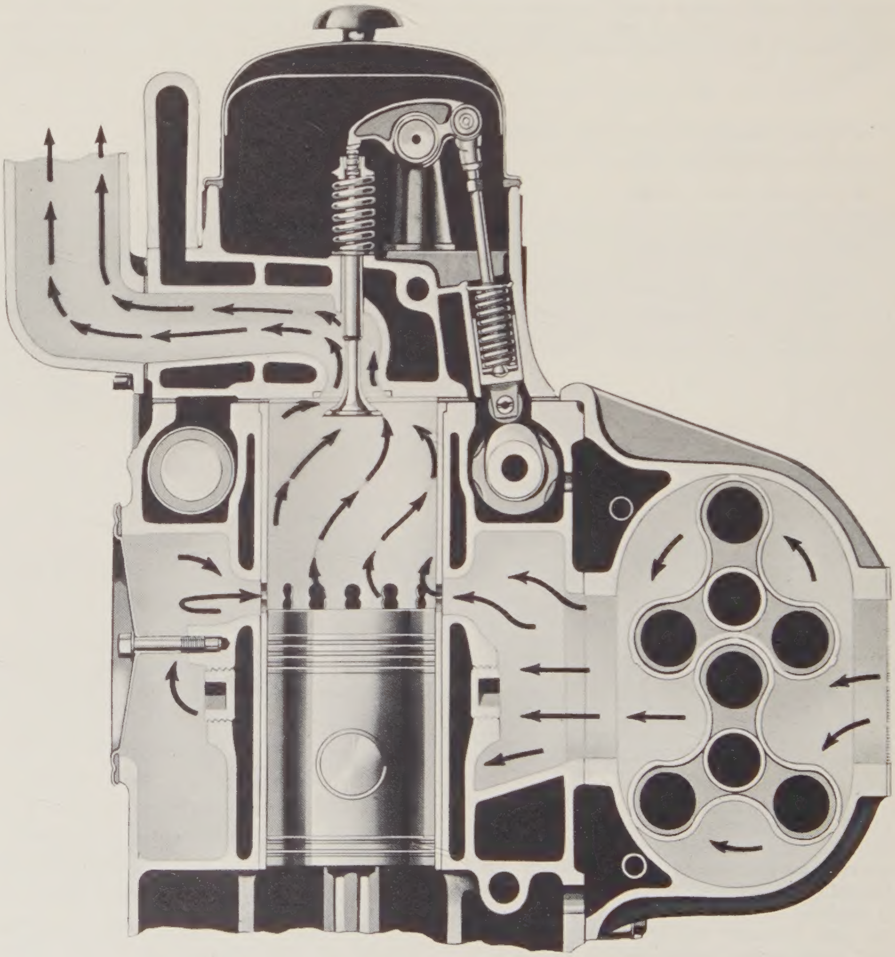


Fig. 2—In a uniflow scavenged, two-cycle Diesel engine maximum air flow areas are achieved and pumping losses minimized by inducting air through inlet ports positioned around the entire periphery of the cylinder and exhausting through the cylinder head. Shown here is a partial cross section of a Detroit Diesel Series 71 engine.

By **HARRY S. FORD, JR.**
and **JOHN J. MAY**
**Detroit Diesel Engine
Division**

New engine design

based on existing

Diesel engine series

Need Arose for Improved Fuel Economy

During the late 1940's and early 1950's the fuel cost advantage of the Diesel engine began to disappear for the following reasons: increased demand for fuel in the Diesel distillation range due to an increase in the number of Diesel engines and jet and prop-jet aircraft; higher fuel taxes; and increased operating costs in the petroleum industry.

In the last few years the price of Diesel fuel has steadily climbed closer to that of gasoline. In addition to rising fuel costs, the vehicle operator has been faced with increased labor costs. Since the vehicle and Diesel engine manufacturer also faced higher labor costs, equipment costs have increased. About the only way the vehicle operator has had to combat these rising costs has been to use less fuel per revenue mile. This, in turn, has resulted in a demand for more efficient Diesel engines without excessive power but with maximum durability.

Early Tests Examined Fuel Consumption Characteristics

During the early 1950's Detroit Diesel Engine Division and GMC Truck and Coach Division conducted a joint series of tests to determine the effect of engine horsepower on average trip speed and average fuel mileage. It was found that an increase in engine power from 184 bhp to 230 bhp (a 25 per cent increase) raised the trip speed six per cent and decreased the fuel mileage almost ten per cent (Fig. 1). The test results were based only on actual road time. Balanced against the slightly increased trip speed was the reduction in fuel mileage, plus the inevitably shorter overhaul period of the engine at 25 per cent higher power.

The situation at the time of the road tests clearly showed that there existed a definite need for improved Diesel engine fuel economy. Improved fuel economy would obviously be of benefit to all users of Diesel power, particularly the highway hauling industry which requires the minimum possible direct operating costs because of its highly competitive nature.

After reviewing all factors involved, Detroit Diesel Engine engineers decided to undertake the development of a new series of Diesel engines which would be designed to give maximum in-service fuel economy. The new engine was to be based on the existing Series 71 engines and was to be designated as Series 71-E. It was contemplated not only to develop the engine to give improved fuel economy but also to design the new engine to have a high degree of parts interchangeability with the existing Series 71.

Development Influenced by In-Service Operating Conditions

Most of the fuel burned by a 200-hp Diesel engine in heavy duty vehicle service (both on and off the highway) is burned at or near governed engine speed. The power at which it is burned, however, varies widely with terrain and gross load. Average operating horsepower of vehicles in the 40,000-lb to 80,000-lb gross weight class is in the neighborhood of 80 bhp to 140 bhp, or 40 to 70 per cent load factor. This is the power range which has the greatest effect upon operating fuel economy.

Satisfactory vehicle performance with a given power train is a function of maximum horsepower and full throttle torque characteristics. At 40 per cent load factor any engine is operating at relatively low mechanical efficiency, and its fuel economy is controlled to a larger extent by its internal friction rather than its combustion efficiency. With these considerations in mind it was decided, therefore, to attack engine friction, and more specifically pumping work, as a first step in developing the new 71-E engine.

Scavenging

A uniflow scavenged, two-cycle Diesel engine has a unique advantage over all

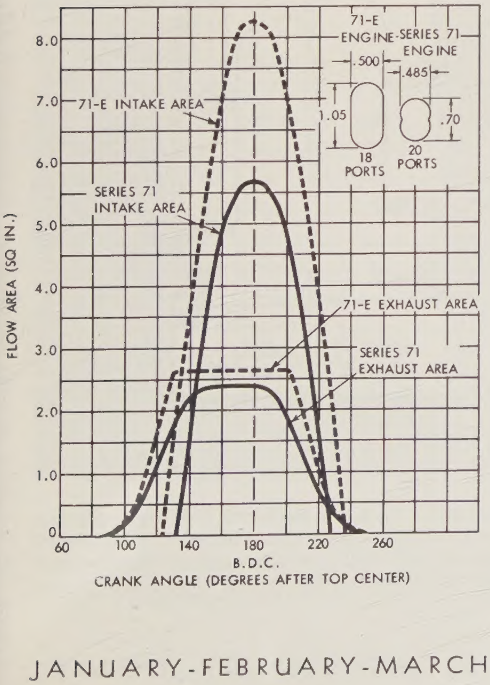
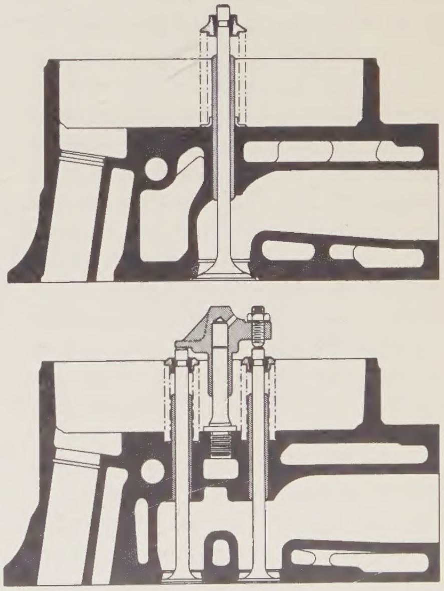


Fig. 3—A comparison of intake and exhaust areas of the Series 71 Diesel engine and the new 71-E engine (left) shows the greater flow areas provided by the new engine. The 71-E engine has 18 air inlet ports of oval design compared to the Series 71 engine's 20 ports of "figure 8" design. The improved inlet port design gives the 71-E engine 58 per cent more intake area. A transverse cross section through the exhaust ports of the Series 71 engine and the new 71-E engine shows the four-exhaust-valve cylinder head used in the 71-E engine (lower right) compared to the conventional two-valve head design (upper right). Use of the four-exhaust-valve arrangement provides 23 per cent more exhaust area in the 71-E engine.



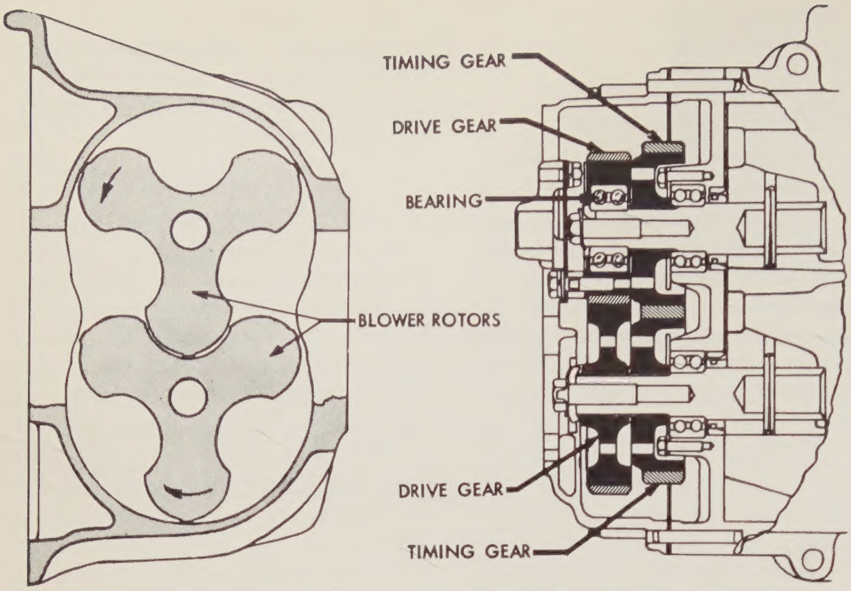


Fig. 4—Blower speed was reduced in the new 71-E engine by adding an additional pair of gears within the lenthened end plate cover of the existing Series 71 engine blower assembly. The upper drive gear is mounted on an anti-friction bearing and mates with a lower driven gear which is splined to the lower rotor. The lower rotor, in turn, drives the upper rotor through the timing gears.

other reciprocating power plants of commercial design. By inducting air through inlet ports around the entire lower periphery of the cylinder, and exhausting through the cylinder head, maximum air flow areas are achieved and pumping losses minimized (Fig. 2).

This feature of the uniflow engine was exploited fully in the development of the 71-E engine. Inlet ports were changed from the standard "figure 8" design to an oval design, and total inlet area was increased by 58 per cent (Fig. 3). Many variations in inlet port size, shape, and guide angle were designed and tested before adopting a 30° oval port. Exhaust areas were increased 23 per cent by using a four-exhaust-valve cylinder head instead of the conventional two-valve design used in the existing Series 71 engine (Fig. 3). The combined effect of the increased inlet and exhaust areas resulted in increasing the effective orifice area of the engine from 2.69 sq. in. to 3.42 sq. in. With the increased area for air flow, the discharge pressure against which the scavenging blower worked was reduced, and engine air consumption increased.

Since the 71-E engine would be required to burn a reduced amount of fuel, air delivery was far higher than necessary, and a reduction in blower drive ratio was possible. A major reduction in blower drive ratio could not be achieved by gear changes in the engine timing gear train without a revision in gear centers. Such a revision would destroy interchangeability of timing gears, flywheel housings, and blower components between the Series 71 and 71-E engines. It was decided, therefore, to incorporate a set of reduction gears within the blower assembly itself (Fig. 4). These gears reduced blower speed from twice the engine speed to 1.69 times the engine speed.

Because of the changes made in flow area and blower drive ratio, a large reduction in the amount of power required to drive the scavenging blower was possible. This was done while retaining more than ample air delivery.

Fire Ring Piston

In a uniflow scavenged Diesel engine it usually is assumed that the top edge of the piston controls the intake port timing. While this is true qualitatively, the piston does not provide a complete

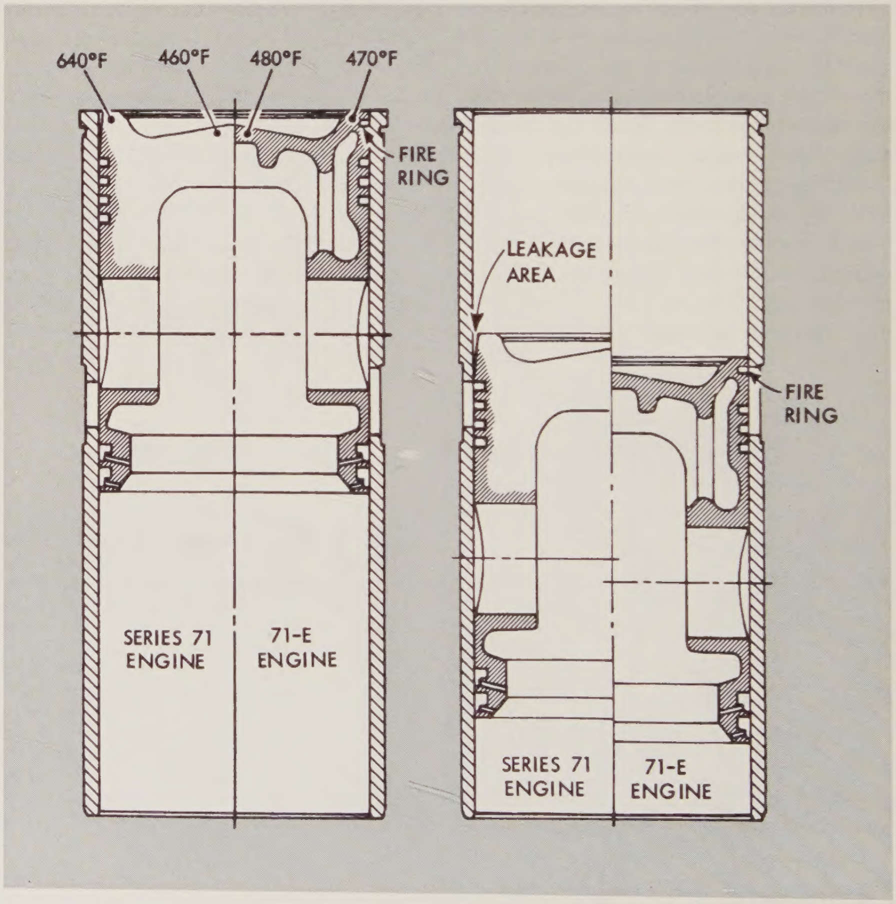


Fig. 5—The addition of a fire ring 1/8 in. below the top of the piston rim in the 71-E engine provides a uniform temperature distribution across the entire combustion chamber, as indicated by a comparison of temperatures between the Series 71 and 71-E engines (left). The fire ring also provides the maximum possible effective compression and expansion stroke by eliminating the leakage of combustion gases around the piston rim (right).

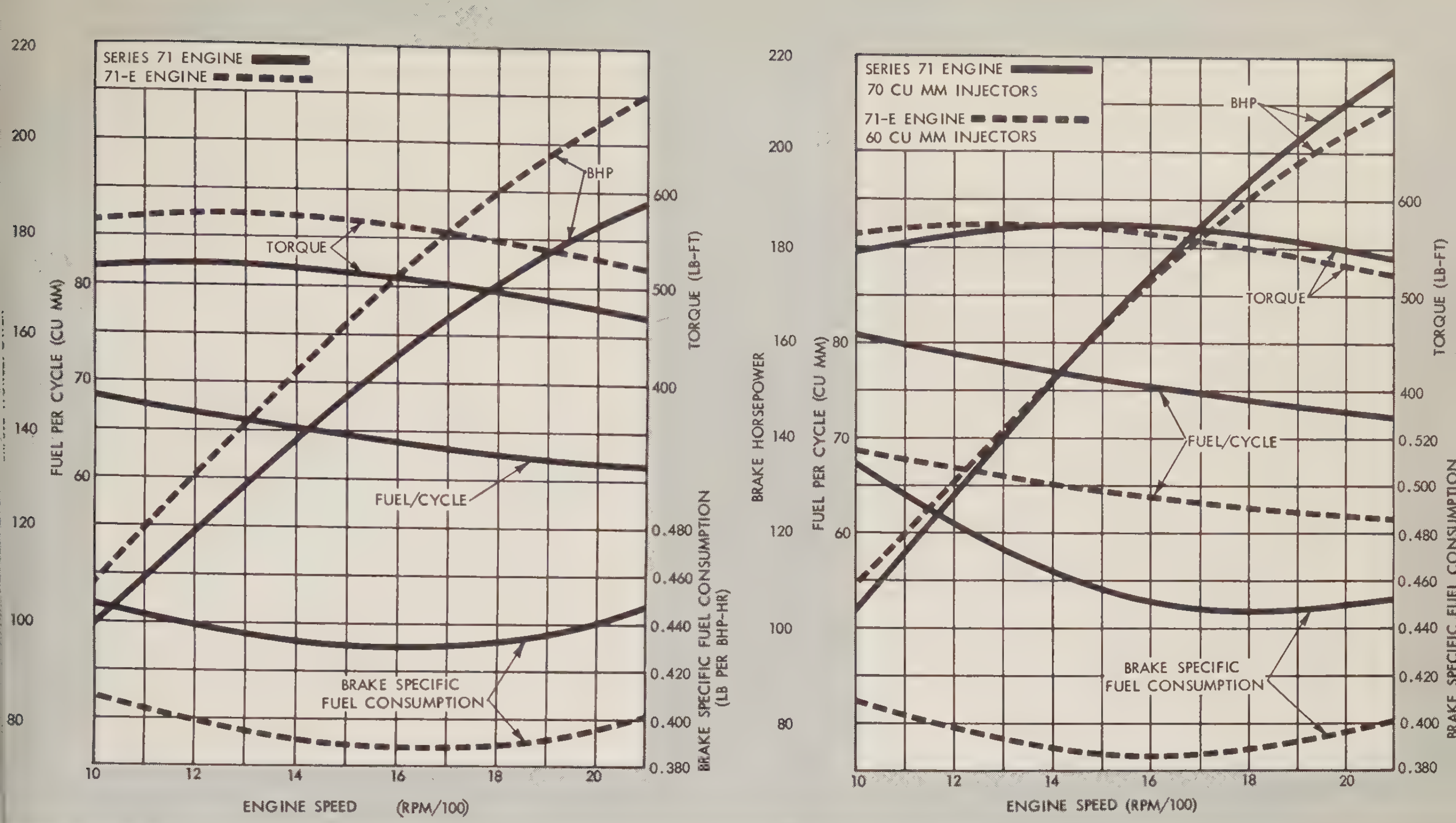


Fig. 6—The full throttle performance comparison between the Series 71 and 71-E engines shown at the left is based on equal fuel input using 60 cu mm injectors in each engine. The full throttle performance comparison between the 71 and 71-E engines, shown at the right, is based on using 70 cu mm fuel injectors for the Series 71 engine and 60 cu mm fuel injectors for the 71-E engine.

seal. There is a finite clearance between the rim of the piston and the cylinder wall which provides a leakage path until the compression rings seal the ports. The area of this leakage path varies with the piston rim temperature, and the major portion of the area is located at the side of the piston opposite to the direction of piston side thrust.

To provide a sharper port cut-off in the 71-E engine, a fire ring was added ⅛ in. below the top of the piston (Fig. 5). In addition to providing the maximum possible effective compression and expansion strokes for any given inlet port height, the fire ring also provided the following beneficial effects:

- All air in the cylinder was trapped above the fire ring and was available for combustion as the piston approached upper dead center on the compression stroke. Also, radial air velocity into the combustion chamber was increased
- The fire ring minimized heat losses by reducing the area of cylinder wall exposed to the burning mixture early in the expansion stroke, when gas temperatures and pressures were highest
- The fire ring reduced by 31 per cent the surface-to-volume ratio of the Series 71 engine cylinder at upper dead center
- The piston rim, normally the hottest

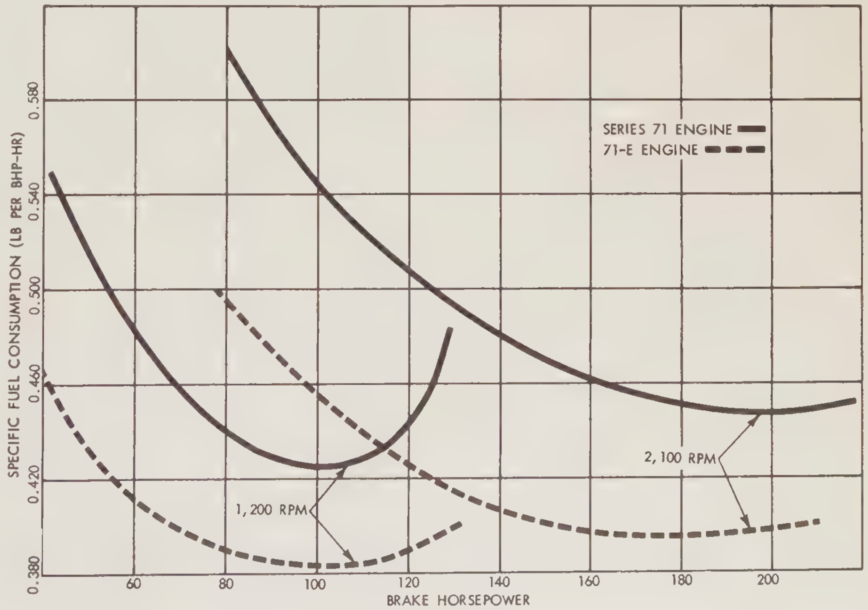


Fig. 7—The magnitude of part throttle improvement in the 71-E engine is shown by this comparison of the Series 71 and 71-E engines at 1,200 rpm and 2,100 rpm. The Series 71 engine used 70 cu mm injectors and the 71-E engine had 60 cu mm injectors.

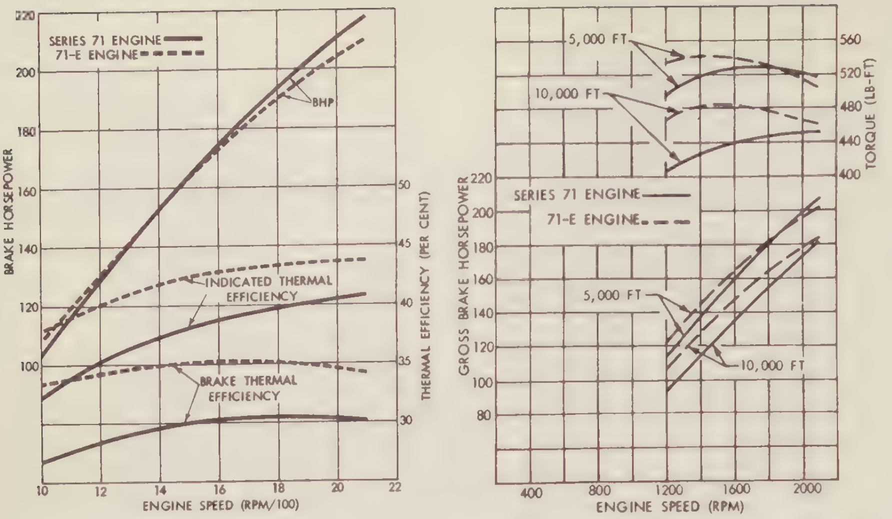


Fig. 8—The improved full throttle thermal efficiency provided by the 71-E engine (left) gives the engine superior performance at high altitudes when compared to the standard Series 71 engine (right.)

part of the piston since it received heat on both top and side, was subjected to a "wire drawing" effect after the rings uncovered the inlet ports on the expansion stroke. Both of these effects were greatly reduced by the fire ring, which brought the temperature of the piston rim down to that of the piston bowl center, and provided a uniform temperature distribution across the entire combustion chamber.

The use of a fire ring improved the indicated thermal efficiency, particularly under heavy load, and permitted a given horsepower to be developed with less injected fuel.

Fuel Injection

Increased air flow areas and reduced blower delivery resulted in a change in the scavenging pattern of the engine. Pressure drop across the inlet ports had been reduced and, therefore, inlet velocity and its tangential component (swirl) also were reduced and made more uniform throughout the engine speed range. In addition, conditions of radial velocity into the combustion chamber and temperature distribution across the chamber were changed greatly, all of which required that the fuel injection characteristics be rematched to the new conditions.

While all of these conditions were known qualitatively, precise data as to instantaneous temperatures, pressures, and velocities at all points in the combustion space under varying speed and load conditions were not known, and complete knowledge of the mechanism of combustion in a Diesel cylinder was lacking. Matching injection characteristics to a given set of combustion chamber conditions was, therefore, a most unscientific process of trial and error, with only slight guidance from what was known of combustion chamber conditions. Optimum combustion in the 71-E engine was obtained with eight spray holes each 0.0055 in. in diameter and an included spray angle of 165°. The spray tip used in the standard Series 71 engine had seven holes each of 0.006 in. diameter with an included angle of 155°.

71-E Engine Provides Improvements in Many Areas

The cumulative effect of the design changes made in developing the 71-E engine is that with the same injected fuel rate the 71-E engine develops between 9 per cent and 12 per cent more bhp than the standard Series 71 engine (Fig. 6-left). Perhaps of greater importance is a comparison of the two engines at approximately equal power (Fig. 6-right). The new 71-E engine also provides a significant reduction in fuel consumption at part throttle operation (Fig. 7). Based on a typical highway hauling operation of 100,000 vehicle miles per year (about

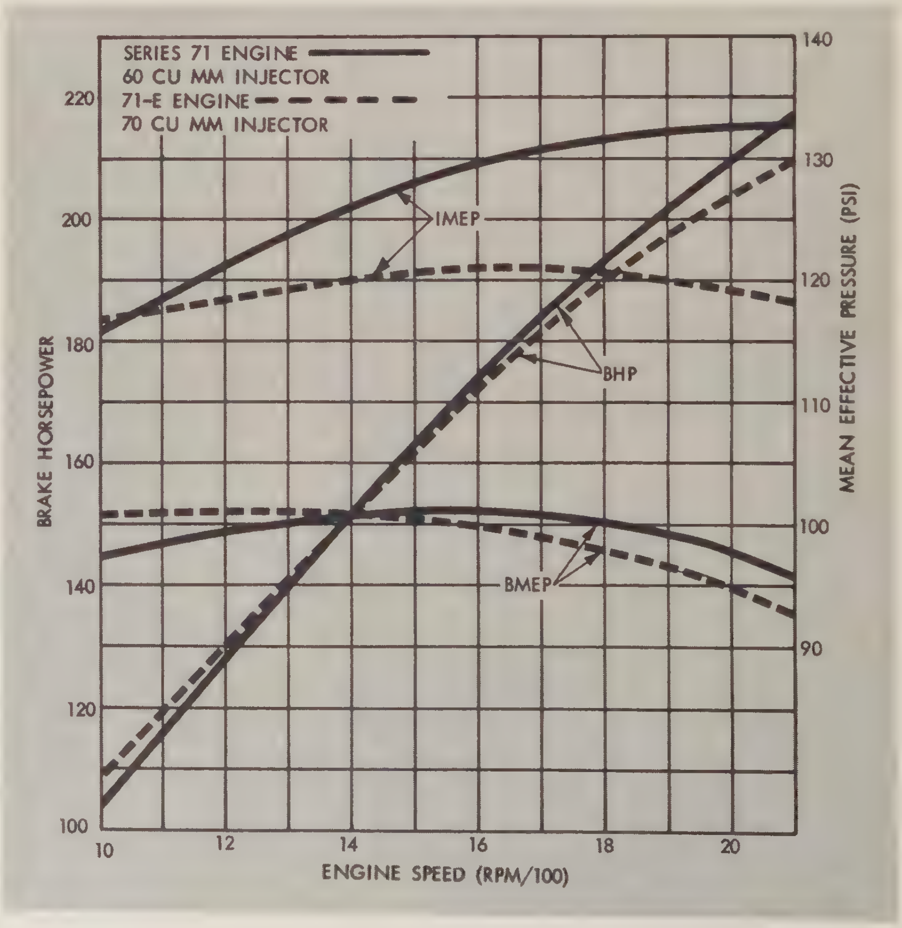


Fig. 9—A comparison of mean effective pressures between the Series 71 and 71-E engines shows that the 71-E engine develops brake mean effective pressures approximately equal to the Series 71 engine, but at very reduced indicated mean effective pressures.

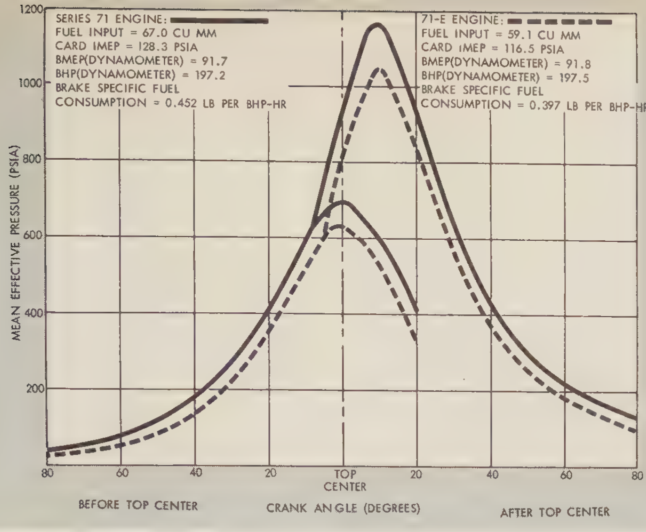


Fig. 10—Comparative pressure-time diagrams of the Series 71 and 71-E engines at equal brake horsepower and an engine speed of 2,000 rpm show the reduced pressure loading on the 71-E engine cylinder components.

3,000 hours) the annual fuel saving obtained with the 71-E engine amounts to approximately 4,000 gallons per vehicle.

Altitude Performance

The improvement in full throttle thermal efficiency provided by the 71-E engine (Fig. 8-left) makes possible several benefits in addition to reduced fuel costs and cleaner exhaust. One of these benefits is superior performance at high altitudes (Fig. 8-right). Because the 71-E engine burns less fuel and burns it more efficiently, less air is needed for combustion. The rate of power loss with increasing altitude, therefore, is considerably less than in the standard Series 71 engine.

Mechanical Loading

The reduced internal friction of the 71-E engine makes it possible to develop brake mean effective pressures approximately equal to the Series 71 engine, but at greatly reduced indicated mean effective pressures (Fig. 9).

The 71-E engine also has a reduced compression pressure (Fig. 10) which is the result of lower cylinder pressure at the start of compression. This, in turn, is the result of free breathing and low charging pressure. The lowered peak and mean firing pressures provided are partially attributable to the lower compression, and partially to the reduced fuel rate. The mechanical compression ratio of the 71-E engine, on the other hand, has been slightly increased and compression heat losses reduced. This provides higher compression pressures and temperatures at cranking speeds. It has been possible, therefore, to improve the starting ability of the 71-E engine, while at the same time reducing gas pressures in the high power range.

Thermal Loading

The thermal load on the combustion chamber parts can be expressed in terms of the heat equivalent of the injected fuel rate per unit of exposed area. The reduced fuel rate of the 71-E engine results in 15 per cent less maximum thermal load on the piston, cylinder head, and cylinder walls (Fig. 11-left). This reduces the maximum piston temperature (rim temperature) by 100°F. The addition of the fire ring causes a further reduction of 170°F in the maximum piston temperature (Fig. 11-right). Similarly, the maximum rate of heat transfer to the cylinder head and exhaust valves has been decreased, thus reducing the temperature range through which they cycle.

Conclusion

Development of the 71-E engine by Detroit Diesel Engine engineers has yielded a cleaner engine with equal power, improved fuel economy, longer life, and superior altitude performance when compared to the Series 71 engine. The intensive design, development, and testing program which produced these results is still extremely active and will continue to be so in order to meet the changing needs of the commercial vehicle Diesel engine.

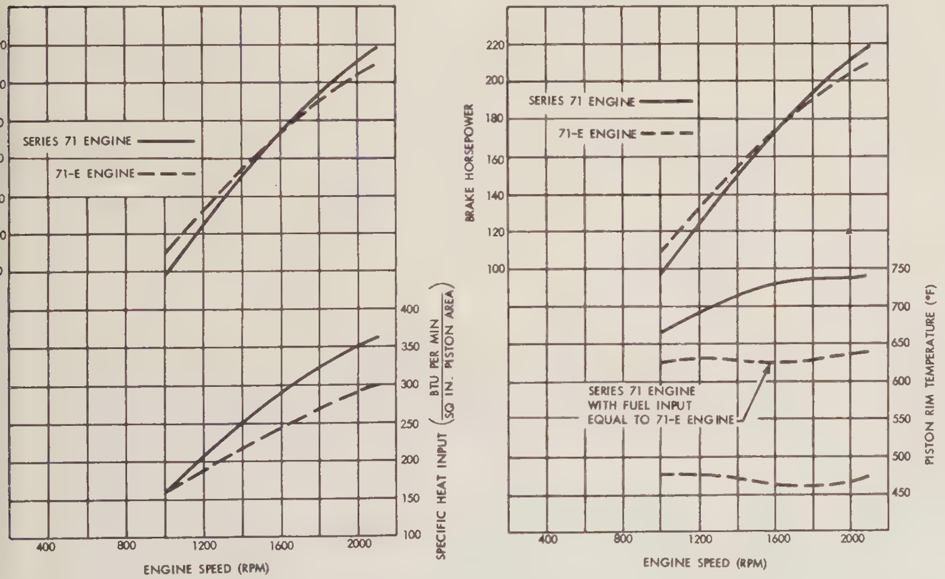
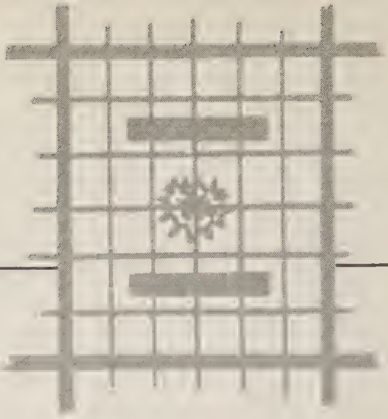


Fig. 11—A comparison of the relative thermal loading between the Series 71 and 71-E engines (left) shows that the 71-E engine has a lower maximum thermal load of about 15 per cent on the piston. This results from the reduced injected fuel rate required by the 71-E engine. Reducing the fuel input of the standard 71 engine from 70 cu mm to 60 cu mm reduced the piston rim temperature 100°F (right). The fire ring resulted in a further reduction in rim temperature of 170°F.

Excerpts from this GM ENGINEERING JOURNAL paper were included in the S.A.E. paper, "GM Diesel's Additional Engines—New 'V's' and Inlines," presented by K. L. Hulsing and C. E. Ervin, Detroit Diesel Engine Division, at the 1959 annual meeting of the Society of Automotive Engineers, held in Detroit, January 12-16

Laboratory Studies of Fire Action Result in Criteria for Emergency Roof Ventilation



Until recently, very little actual experience or knowledge has been available concerning a particular type of fire hazard—the rapidly accelerating fire in a large, undivided flat-roofed industrial building. To secure more knowledge about the behavior of such fires and to suggest possible additional protective measures, General Motors sponsored a research program at the Armour Research Foundation, Illinois Institute of Technology. The results showed that certain conclusions could be translated into recommendations for use by General Motors plants. The type of fire studied produced large quantities of hot gases at the ceiling. The heat from these gases could cause severe damage, not only from combustion, but also from structural failure of the building framework. This condition suggested some system of emergency gravity roof ventilation to exhaust part of the hot gases quickly, and thus retard the rapid spread of the fire.

THE PROBLEM of emergency roof ventilation to aid fire control and minimize damage was the subject of a recent study to determine whether standards could be established for application to certain kinds of industrial buildings.

This program was undertaken to learn more about a phenomenon of fire action which could affect the fire safety of many modern industrial buildings with flat roofs over large, undivided manufacturing areas. In buildings of this type, the spread of smoke and hot gases generated by an accelerating fire can be so rapid that the resulting concentration of heat contributes to the fire damage, not only through actual combustion, but also through structural failure due to rapid overheating of the structural framework of the building.

This phenomenon suggested that a system of gravity ventilation designed to exhaust quickly the smoke and hot gases generated by a relatively small fire within a building would prevent the rapid and extensive propagation of the fire. Such a system would offer added protection to the relatively large floor areas required for efficient, large scale production operations.

Since very little recorded experience and few technical facts about such fires were available, General Motors proposed a study of the physics of this particular fire action to obtain fundamental data on which to base suitable standards for emergency ventilation. Consideration was given to the construction of a full-size test building with equipment and instrumentation to simulate and record fire and ventilation phenomena. Further study indicated that such a project, besides being costly, would limit the research to an inadequate investigation of the innumerable factors comprising fire conditions. It was decided, therefore, that Argonaut Realty Division of General Motors would sponsor a research program at the Armour Research Foundation, Illinois Institute of Technology, Chicago, Illinois. Working with Argonaut Realty engineers, the Armour Heat-Power Research Laboratory demonstrated the feasibility of using a scale model industrial building with fire and smoke generating equipment and instrumentation to conduct the necessary studies.

The results of the program showed that a number of conclusions could be drawn affecting the use of: (a) roof ventilators and monitors, (b) draft curtains at the ceiling, and (c) ratios of floor areas to vent areas. The data and conclusions were thoroughly studied and translated into recommendations by the General Motors Building Code Committee, which is made up of Divisional plant engineers and other executives experienced in

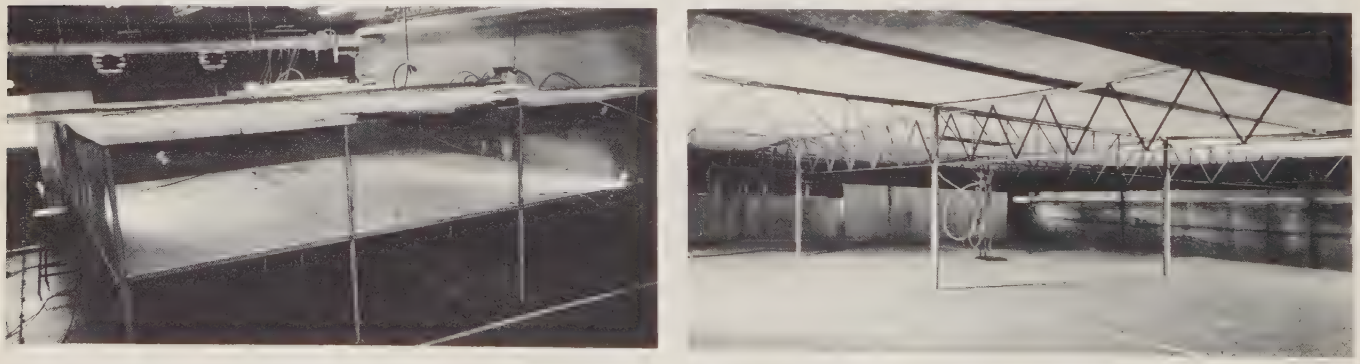


Fig. 1—The model used in the GM-sponsored program at Armour Research Foundation was constructed of a welded steel framework with a roof and floor of flat asbestos cement board (left). The 15-ft by 18-ft model was equipped to conduct studies at two scales by adjusting the height of the floor. Provision was made to enclose each bay, or only the perimeter of the model, with draft curtains. For some studies the interior draft curtains were replaced by simulated trusses (right). A gas burner of concentric rings was used to simulate a fire. It had a flexible gas feed line which facilitated changes in fire location. For studies at 1/8 scale, the model had 9 bays, each 5 ft by 6 ft, with a 30-in. ceiling. This represented a building with a 20-ft ceiling with 40-ft by 48-ft bays having a total area of 17,280 sq ft. The model used for 1/16 scale studies contained 36 bays, each 2-1/2 ft by 3 ft and had a 15-in. ceiling. This represented 36 bays, each 40 ft by 48 ft, with a total area of 69,120 sq ft and a 20-ft ceiling. The size of the gas burner was adjusted to correspond with the scale of the model. Use of a scale model building proved to be an efficient way of obtaining the data of this study. The heat vented through roof openings in the model represented with reasonable accuracy the relative amounts of heat which would be vented from a full size building.

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Added fire protection for
industrial buildings through
scale model studies

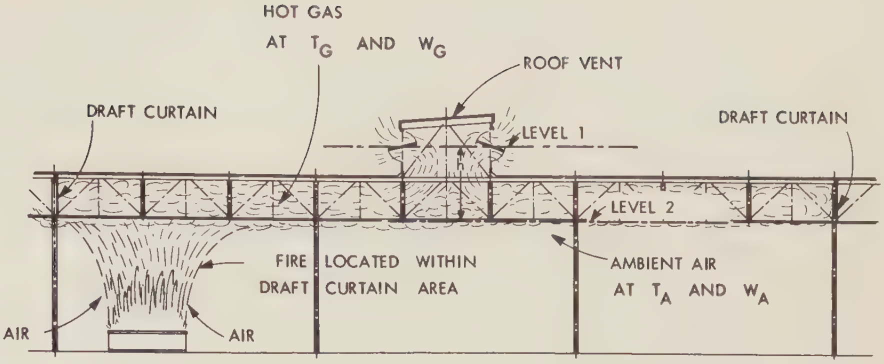


Fig. 2—The formula derived to show the relationship of factors affecting the heat vented is based on the assumption that a steady state condition of temperature distribution exists between levels *1* and *2* as shown by this sketch.

industrial building construction.

The recommendations, of course, applied only to General Motors plants and there was no intention that the recommendations should relate to existing standards of other organizations or that they would replace other fire protective measures, such as sprinkler systems. The recommendations, also, were not considered as hard and fast rules; they were subject to reasonable interpretation, in both existing and proposed buildings.

Development of Venting Equation Permitted Scale Model Studies

The test program investigated the problems of selecting optimum sizes and locations for roof ventilators and monitors. In addition, such problems as the effect of draft curtains, ceiling height, and certain secondary influences, including sprinklers, wind effects, and transient temperatures were investigated.

In conducting the model building studies in the laboratory, investigations were made to determine the scale relationships linking the results from the experimental studies to prototype conditions. These investigations included the finding of model similitude ratios of temperature, hot gas velocity, time, and rate of heat released by the fire and relieved by the ventilators (Fig. 1).

Prior to the model studies, the laws of similitude were derived from an analysis of the underlying physical phenomena by assuming basic flow and venting conditions. Thus, the much less expensive and more controllable tests on a small scale model established the essential features of physical action which occur during a fire in a full scale building.

The most significant assumptions used in the derivation of the venting formula were that a steady state condition of temperature distribution and a convective flow of hot gases existed. Reduced to the simplest equation, the output of heat generated by the fire—representing all the heat vented through the roof, dissipated inside the building, and absorbed by the structure (expressed in Btu per minute)—must equal the input of heat calculated from the volume and heat of combustion of the fuel, expressed in like terms. By the use of Bernoulli's equation, the following formula was derived to show the relationship between these factors and the heat discharged from the roof vents (Fig. 2):

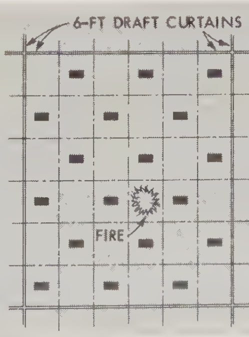
$$H_v = 60(A)\,(C_d)\,(c_p)\,(w_a)\,(T_a)\sqrt{\frac{2gh}{1+k}}\left(\frac{\dfrac{\Delta T}{T_a}}{1+\dfrac{\Delta T}{T_a}}\right)\sqrt{\frac{\Delta T}{T_a}}$$

where

H_v = heat vented (Btu per min)
A = area of vent (sq ft)
C_d = vent discharge coefficient
c_p = specific heat of hot gas (Btu per lb °F)
$\Delta T = T_g - T_a$ = temperature of hot gas (°R)
T_g = absolute gas temperature (°R)
T_a = absolute ambient air temperature (°R)
w_a = weight density of gas (lb per cu ft)
g = acceleration due to gravity (ft per sec^2)
k = coefficient of velocity head loss through the vent
h = effective chimney height (ft).

Where the main physical action in a full scale fire is caused by "chimney action," the above formula can be used to compare the amounts of heat vented in the model and an actual building. Due to some secondary conditions, the given relationship is not completely accurate in all cases, but proved dependable within the limits of this program.

Since the amount of heat exhausted by a vent is directly proportional to the mass flow rate and temperature rise of hot gases above ambient, studies showed that a reduction to a model scale required that the heat output be scaled down by the five-halves power of the scale factor. The other basic elements of the experiments, that is, temperature, velocity, and fire size, showed definite similitude relationships. For example, a model at one-quarter full size required a fire reduced to about 3.5 per cent and resulted in gas velocities at 50 per cent of



NUMBER OF 8-FT BY 16-FT UNIT VENTS OPEN	HEAT VENTED	VENT-TO-FLOOR RATIOS
4	25%	1:135
9	50%	1:60
18	80%	1:30

Fig. 3—One of the first studies with the model was to examine the general area protection offered by a series of roof vent openings with a draft curtain provided only around the perimeter. This experiment was conducted at 1/16 scale and the model represented 36 bays. The table compares the amount of heat vented with 4, 9, and 18 vents opened.

full scale, using the same temperatures for both model and full scale conditions.

Laboratory tests confirmed these scale factor relationships and also showed that the amount of vented heat was approximately a constant ratio of the fire heat, as the scale model factor was changed.

Although the studies proved to be accurate, all details of plant conditions could not be simulated in the laboratory tests. Such details were minimized where possible, and the tests were evaluated with caution and proper judgment. Analysis showed that both velocity and time varied with the square root of the scale factor; therefore, the time of transient occurrences in the model was much less than clock time. Such an acceleration of time thus precluded conducting model experiments based on transient conditions including accelerated increases in fire intensity.

For all studies conducted under steady state conditions, adequate time was allowed for the structure to attain a temperature equilibrium and an established air and gas flow pattern after the fire was started and before any test data were recorded. The principal data obtained were heat flow through vents or monitors, determined by temperature and velocity measurements of the gases being exhausted. Temperatures were measured by thermocouple probes, and velocity measurements were taken with a velometer modified and calibrated for that special purpose. In some experiments, temperatures of hot gases near the model ceiling were measured by thermocouples placed at various locations about ⅛ of an inch from the ceiling. For transient temperature measurements, a multiple-channel continuous recorder was used with the thermocouples.

The total heat release by the gas burner was determined by multiplying the lower heating value of the gas by the metered rate of gas supply. After completion of each test, the atmosphere in and around the model was ventilated and allowed to cool. By the use of titanium tetrachloride, which forms a dense white smoke upon contact with air containing a minimum of water vapor, the air and hot gas flow patterns were made visible and could be photographed.

Unit Type and Monitor Type Vents Used

The research program was designed to study two types of venting devices: *unit* type vents and *monitor* type vents. The unit type vent is defined as a weather-tight structure installed on a building roof to provide a relatively small opening for gravity exhaust of smoke and hot gases from a fire within the building. The general effectiveness of unit vents is determined by the temperature of the gases directly below the vent opening. This temperature is controlled by many factors such as size, type, and location of fire, size and spacing of vents, depth and location of draft curtains, size of draft curtain area, ceiling height, cooling effect of water sprinklers, and others.

Unit Type Vent Performance Affected by Various Conditions

The first experiments on the model were to establish basic information regarding the unit venting characteristics. The model was arranged with a series of 18 vent openings in a checkerboard pattern on the roof, representing a 36-bay building at 1⁄16 scale. Draft curtains were provided around the perimeter only (Fig. 3). These curtains were noncombustible panels attached to the roof trusses to retard the hot gases from spreading outside the enclosed area. In the first study, all vent openings were closed to simulate an unvented building. The draft curtain area rapidly filled with hot gases, which spread under the curtains into adjacent areas. In an industrial building, this would be an extremely hazardous condition. In subsequent studies, four, nine, and finally all 18 vents were opened to give the percentages of heat vented (Fig. 3).

Vent-to-Floor Area Ratio

A variety of experiments at 1⁄16 scale, using from 4 to 18 open vents of 64 sq ft or 128 sq ft, with 6-ft draft curtains around 9, 16, and 36 bay areas with a 20-ft ceiling, established the general venting curve for uniformly distributed open unit ventilators (Fig. 4). This curve gave the per cent of heat vented as a function of the ratio of the total vent area to floor area, under the conditions simulated. It should be noted that the experiments involved uniform distribution of unit vents with the assumptions that all the vents within the draft curtains were open and that the steady state prevailed.

From this basic information, the program proceeded to investigations of the principal factors and limits involved, to enable a more comprehensive and dependable interpretation of the general ventilation curve.

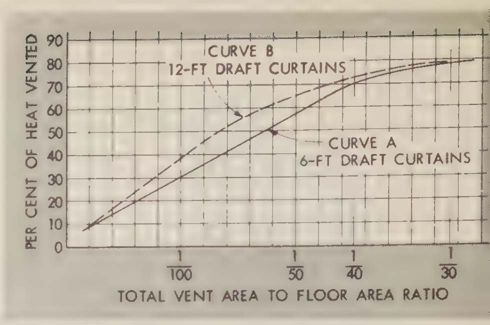


Fig. 4—From a variety of experiments at the 1/16 scale, a general venting curve was established. These experiments involved uniform distribution of unit vents in a repeating geometrical pattern, with the assumption that all vents within the draft curtain area are open and that the steady state prevails. With floor area ratios greater than 1 to 50, the gain in heat vented becomes smaller, until at 1 to 30 the upper venting limit of 80 per cent is reached. This limit, representing the approximate amount of heat vented by convective effects, was established by the analysis of all measurements. In calculating the percentages of heat vented under the various sets of conditions, it was determined that about 20 per cent of the generated heat was dissipated by radiation and conduction within the building and through the structural components, such as the roof and supporting steel.

Vent Spacing

In addition to knowing the proper ratios of vent-to-floor areas required to give adequate venting, it was necessary to determine the maximum allowable spacing between vents.

The major factor affecting vent spacing was the variation in temperatures near the ceiling throughout the draft curtain area around the fire. After determining the variation in several experiments with the fire in several locations, it was found that the hot gas temperatures decreased rapidly as the gases traveled away from the fire. This made it desirable to place the vents not more than 50 ft from any possible fire location. The limit was lengthened, however, to one diagonal bay distance (about 63 ft) to give a practical pattern of one vent for each four bays (Fig. 5).

Draft Curtains

In analyzing the effects of varying the size of draft curtain areas on both uniform and non-uniform geometrical vent distribution, the general vent performance was found to be insensitive to variations in draft curtain areas. Thus, with the same vent-to-floor area ratio, the higher gas temperatures maintained in the smaller areas enabled each vent to operate more efficiently. It was concluded that the size of draft curtain area did not affect the total amount of heat vented, with all vents open in a uniformly distributed pattern.

Next, studies were made of the effect of varying the draft curtain areas while maintaining a constant number of vents, thus giving non-uniform vent distribution. The percentage of heat vented decreased rapidly with increasing draft curtain areas, while the greater decrease occurred when the similar vent-to-floor geometry was maintained, since the vents were moved to cooler regions away from the fire (Fig. 6).

The effects of draft curtain depth were checked by using a 4-vent arrangement in several sizes of draft curtain areas, with varying vent-to-floor area ratios. An increase in depth from 6 ft to 12 ft increased the amount of heat vented in varying percentages, depending on the draft curtain area. The most significant improvement was between the 1:100 and 1:50 ratio range (Table I).

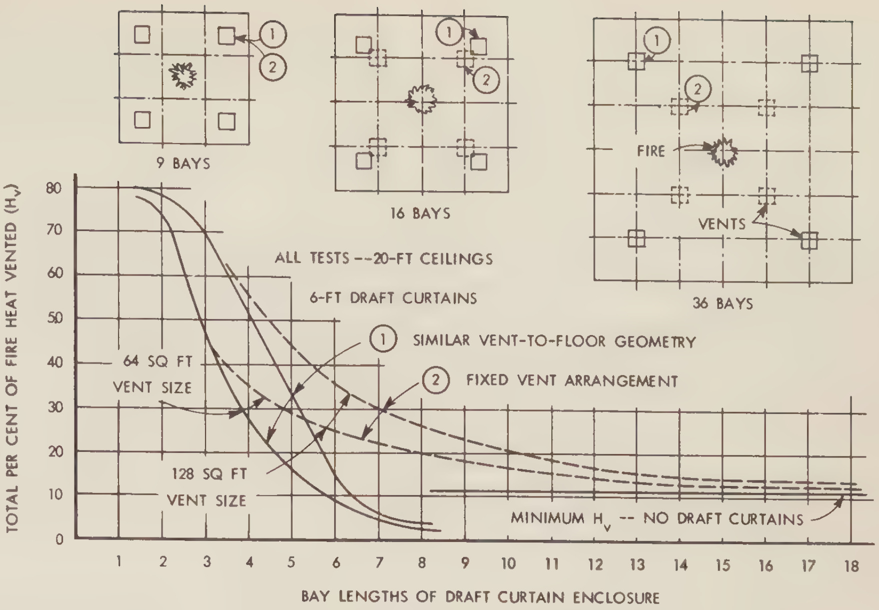


Fig. 6—The effects on emergency venting by increasing the draft curtain area while keeping the total vent area constant are shown on this graph. The two sizes of vents were tested separately. Vents were arranged in two ways: *1* a similar vent-to-floor geometry was maintained, and *2* a symmetrical and fixed arrangement was used.

Building Height

The effects of building height upon venting action were determined by a comparison of tests using 20-ft and 40-ft ceilings. The greatest differences occurred directly above the fire, with temperatures of 1,200°F at the 20-ft height reduced to 450°F at the 40-ft height. The ceiling gas temperatures in both cases were shown to be nearly the same beyond a 90-ft radius from the fire. Studies of four vent patterns showed that unless vents are in a pattern less than two bays apart, reasonable variations in ceiling height had no significant effect on venting action.

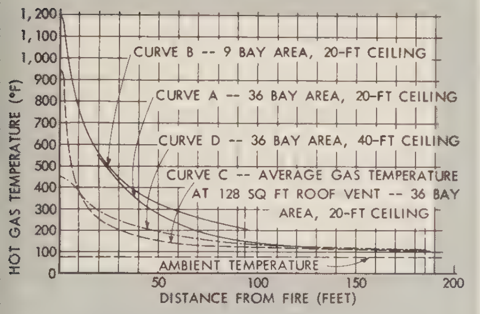


Fig. 5—The variation of hot gas temperatures near the ceiling and within the draft curtain area, in relation to distance from the fire, is shown on this graph. The studies from which the data for this graph were taken were conducted using unit vents with various vent-bay arrangements. One application of this graph is to show in which areas automatic sprinklers can be expected to function. Probably all sprinkler heads set to operate at 165°F would open in the nine bay area for test conditions shown by curves *A* and *B*. These conditions indicate that the area of sprinkler operation does not vary to a large degree between the 9-bay and 36-bay areas. Confined areas smaller than 9 bays, however, would concentrate operation of sprinklers to fewer heads. The higher temperatures indicated at the edges of the smaller (9-bay) areas would result in faster, more positive sprinkler action than in the larger areas. It should be noted that when a unit vent was opened the average temperature of the gases passing through the vent was lower than temperatures at that location when the vent was closed. This was caused by the lifting action on cooler gases at lower levels and the resultant mixing with the hotter gases.

The discussion of ceiling temperature variations indicates that automatic operation of vent dampers actuated by fusible links would be limited to the vents closest to the fire. This would call for either a manual opening of vents or an interconnected control system to open simultaneously all vents within a draft curtain area whenever any one of the vents opened. Otherwise, the entire venting efficiency would be retarded.

To simulate actual conditions in the studies, the vents nearest the fire were opened first. More vents were opened subsequently to show that unless all vents were opened by positive means, the use of a small draft curtain area would be required to assure efficient venting.

Heat Output

The effects of heat output on venting were studied using various sizes of fires. The results showed a linear relationship with a slight reduction in heat vented for the larger fires. For practical purposes, the per cent of heat vented had a constant value; therefore, the general venting curve could be applied directly to all fire sizes with reasonable accuracy.

Fire Location

Fire locations were found to have varying but generally little effect on overall venting efficiencies. When the fire was

Table I—A summary of vent-to-floor area ratios and the per cent of heat vented, for a uniform repeating pattern of open roof vents of unit type, shows that the heat vented is a function of the ratio of the total vent area to the floor area. The summary also shows the effects of draft curtain depth on per cent of heat vented. Definite design limits concerning vent-to-floor area ratios cannot be recommended purely from the model studies, since consideration must be given to the effects of heat and smoke on personnel, burning and smoke producing characteristics of various fires, and many other influencing factors.

PER CENT AREA (TOTAL VENT AREA DIVIDED BY FLOOR AREA)	VENT AREA RATIO (1 SQ FT OF VENT AREA TO X SQ FT OF FLOOR AREA)	PER CENT HEAT VENTED THROUGH ROOF DRAFT CURTAINS 6 FT	12 FT
3.33	1:30	80 (MAX)	80
2.50	1:40	70	73
2.00	1:50	58	66
1.67	1:60	53	62
1.33	1:75	45	55
1.00	1:100	30	38
0.67	1:150	24	30
0.50	1:200	17	21

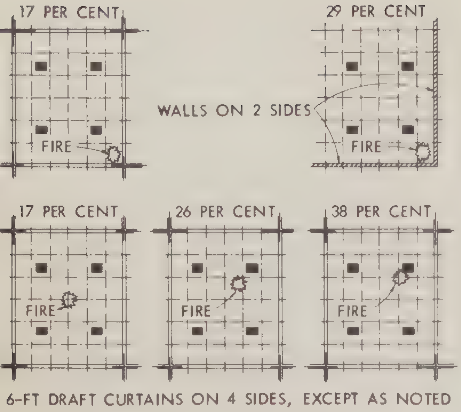


Fig. 7—Studies conducted to show the effects of fire locations on per cent of heat vented gave the results shown here. Fire location was found to have little effect on heat venting efficiency, unless the fire was directly beneath a vent or near a wall or corner, which locations improved the venting efficiency.

near or directly beneath a vent, or near a wall, venting efficiencies improved (Fig. 7). When the fire was near a wall, the hot gases which normally passed outwards were restrained and moved in other directions. The temperature near the ceiling increased, thereby improving the venting efficiency greatly in spite of the complications set up in the flow patterns of the hot gases.

Two control experiments conducted with the fire location studies indicated the benefits of draft curtains regardless of fire location. Under duplicate conditions, the addition of draft curtains increased greatly the amount of heat vented.

Studies were conducted to determine the proper size of vent opening required directly over a recognized fire hazard, such as paint spray areas or furnaces. A series of studies showed that a 50 sq ft opening vented a major per cent of the heat, with a substantial reduction in temperatures nearby.

Monitor Type Vents Offer Good Characteristics

The second type of roof ventilator studied was the monitor type vent, defined to include all sizes of ventilators requiring relatively long and narrow roof openings. These sizes ranged from conventional building monitors one bay in width, extending the length of the building, and having vented sash in the side walls, down to small monitors not less than 4-ft wide and having any required length and height to standard sash.

Using the building model at 1/16 scale, different monitor arrangements were investigated, including monitors of 4-ft and 8-ft widths and of continuous and discontinuous type. (Continuous monitors extend the length of a building, while discontinuous monitors are separated to provide access aisles on the roof.) Other experimental conditions were a 36-bay draft curtain area, 6-ft draft curtain depth, centrally located fire (except in two cases), and a 20-ft ceiling.

Studies were run to show the per cent of heat vented by several different monitor arrangements. It was learned that the 4-ft and 8-ft wide monitors differed very little in heat venting efficiency, but that the 8-ft monitors were more practical and offered greater protection in larger fires. The maximum efficient distance between monitors of both types was found to be three bays. Using various patterns of discontinuous monitors revealed that a staggered arrangement gave better venting than an in-line placement (Fig. 8).

Experiments showed that, although venting efficiency was improved slightly when the fire was near a wall, monitors should be placed as close to walls as possible to prevent heat build-up in these areas.

Although the monitors provided slightly less heat venting than the unit vents, the use of monitors or long narrow vents resulted in a more positive venting action. This shape of ventilator opening acted as a heat and smoke barrier in that essentially all the hot gases flowing toward the monitor were quickly vented. Practically no heat escaped beyond the continuous monitor, but a portion did circumvent the discontinuous monitors, usually in circular flow patterns with some venting along the far side of the openings. This straight line positive venting action of the gases being exhausted directly from a fire by a continuous vent gave the graphic effect of an inverted waterfall of dense smoke pouring over a dam or long weir formed by the edge of the opening. Because of this positive barrier action, long monitors performed similarly to draft curtains in restricting the spread of gases. It was concluded, therefore, that draft curtains parallel to the continuous monitors may be eliminated, with only those transverse to the direction of the monitors being necessary. Draft curtains are required on all sides of an area if discontinuous monitors are employed.

The spacing of monitors was affected by the same factors as in the case of unit vents. With greater spacing, gas temperatures and velocities were reduced because of the larger building area in which the heat could be dissipated by radiation and conduction; also, greater percentages of gas were lost under the draft curtains.

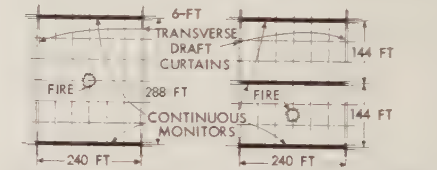
Monitors appeared somewhat less favorable than unit vents when compared on a basis of total vent area, since the center area in larger monitors was not fully utilized by the flow of hot gases (Fig. 9). However, the positive nature of the venting and the barrier action, representing double duty by the continuous monitor as a vent and a draft curtain, indicated that this type of vent is generally preferable to the unit vent.

Several Secondary Factors Also Studied

Some of the many factors present in an industrial building, and which affect venting of hot gases, were not within the range of the research program. A few, however, were of sufficient importance to examine briefly.

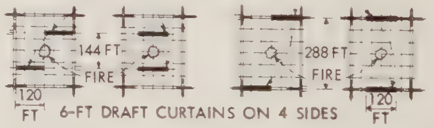
Water Sprinklers

Detailed studies showed that the presence of sprinkler water spray did not reduce the total venting requirements.



MONITORS SPACING (FT)	MONITOR WIDTH (FT)	PER CENT HEAT VENTED	VENT-TO-FLOOR RATIO
288 (6 BAYS)	8	25	1:36
288 (6 BAYS)	4	25	1:72
144 (3 BAYS)	8	78	1:18
144 (3 BAYS)	4	69	1:36

8-FT WIDE DISCONTINUOUS MONITORS



MONITOR SPACING (FT)	PER CENT HEAT VENTED	VENT-TO-FLOOR RATIO
144 (3 BAYS)	41	1:36
144 (3 BAYS)	31	1:36
288 (6 BAYS)	22	1:72
288 (6 BAYS)	19	1:72

Fig. 8—Different monitor vent arrangements were examined and gave the results shown here. The continuous monitor arrangements (top) included only transverse draft curtains. The maximum distance between monitors to produce adequate venting was found to be three bays. The discontinuous monitor arrangements (bottom) had draft curtains on all sides. The best arrangement for discontinuous monitors was to stagger them at a maximum distance of three bays apart. Continuous monitors proved to be the more efficient of the two designs.

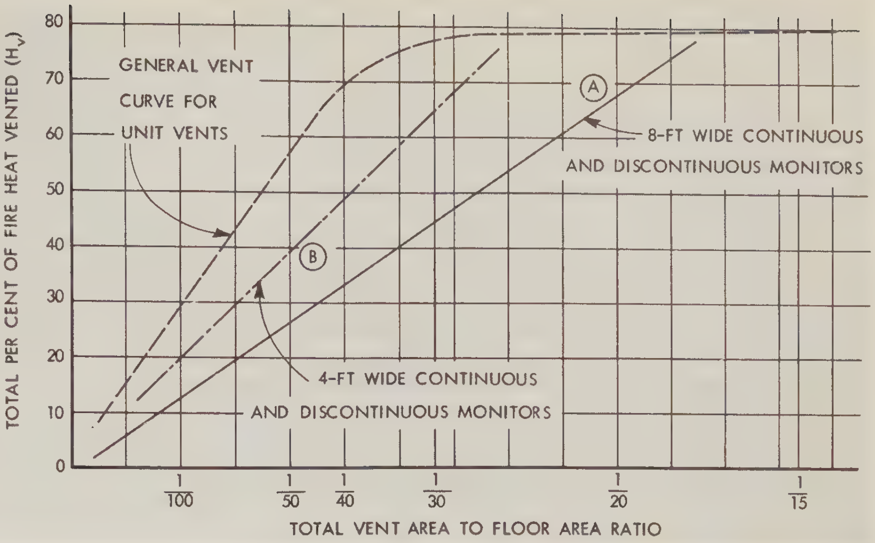


Fig. 9—The monitor venting efficiencies, including all conditions of spacing and widths for both types of monitors, have been plotted in terms of total vent-to-floor area ratios. The general venting curve for unit vents (Fig. 4) has been reproduced for comparison. Curves *A* and *B*, established from data on 4-ft and 8-ft wide monitors respectively, appear at first glance to be unfavorable when compared to the general venting curve. This opinion agrees with test observations of flow patterns, which clearly showed that the 8-ft. monitor openings flowed only about half full of hot gases, whereas the entire width of 4-ft monitors was occupied by the flow. If only the effective width of the 8-ft monitors is considered in the computation of the vent area, the vent curve for monitors will shift and provide generally good agreement with the curve for unit vents. The portion of vent area in monitors in excess of the 4-ft effective width is considered beneficial in handling the ever increasing volume of smoke and hot gases from a large fire and will provide plenum space for collecting smoke before it can be vented through the side sash.

Due to heat absorption by water, the amount of heat to be vented was smaller, but was contained in relatively cooler gases traveling at slower velocities. The total venting area required to maintain venting efficiency, therefore, could not be reduced.

Negative Air Pressure

An analysis was carried out by computation to determine the effects of negative air pressure conditions, prevalent in some manufacturing buildings, upon emergency gravity ventilation of gases and smoke. It was found that negative pressure, due to exhaust fans, is likely to interfere seriously with the proper functioning of roof vents, since the negative pressure tends to counteract the positive pressure driving force which is formed by the chimney action of the hot gases. Thus, where adequate roof vent opening is provided, it appears generally advisable to shut off power exhaust systems in the event of fire.

Transient Effects

The importance of the initial transient time period immediately following the start of a fire was studied for the effects on venting. It was found that the time involved in the spread of hot gases before reaching approximate equilibrium conditions was so brief that this transient effect was relatively insignificant.

Wind Effects

A brief analysis of wind effects upon venting was conducted on the basis of previous studies of wind pressures on large buildings, as reported by other researchers. It was concluded that if monitors are oriented parallel to prevailing wind direction downdrafts into a building would be less probable and venting might be increased on the leeward side. Wind effects could be a factor in orienting buildings to effect better emergency ventilation.

Glass Breakage for Vent Openings

Another secondary problem which was studied was the effectiveness of breaking glass in monitor sash as a means of obtaining ventilating area. Spraying cold water on glass heated by fire gases is not a reliable method, since it requires a sufficiently high temperature around the monitor glass. The temperature distribution curves of Fig. 5 indicate that at distances greater than 70 ft from a fire the gases in a monitor already are cooled to less than 200°F, so glass breakage would not necessarily occur. It was concluded, therefore, that glass breakage from sprinkler water spray was not a dependable means of obtaining a vent opening in monitor sash and that some manual or automatic method of opening the sash should be provided.

Conclusions

The results and conclusions from this study of emergency ventilation were thoroughly analyzed and translated into recommendations which were submitted to all manufacturing Divisions of General Motors. In summary form, these recommendations are:

- Emergency roof ventilation should be provided in all new and existing buildings through the combined use of roof ventilators, or monitors and draft curtains, for effective emergency smoke and heat release
- Gravity type roof ventilation should provide minimum vent-to-floor area ratios of 1:150 in areas of minor hazard, 1:100 in areas of normal hazard, and 1:30 in areas of special hazard
- Roof monitors for ventilation should be provided in all new buildings, should be as continuous as possible, and should be spaced with distances between sash in near sides of adjacent monitors, not to exceed 160 ft, 120 ft, and 80 ft, respectively, for areas of minor, normal, and special hazard
- In existing buildings, small monitors or continuous type ventilators, at least 4 ft wide, should be installed, using the same maximum spacing as for monitors. Unit type vents used singly or in groups, where interferences preclude the use of monitors, should be located generally in repeating patterns, symmetrical with walls or draft curtains
- Draft curtains constructed of sheet metal or other noncombustible materials should be installed in truss areas to divide building areas of minor or normal hazard into draft curtain areas not greater than 70,000 to 100,000 sq ft, depending upon bay sizes. Draft curtains should be not over 300 ft apart in these types of occupancies. In areas of special hazard draft curtains should be not over 150 ft apart. In monitor or sawtooth roofed buildings only transverse draft curtains are required; however, they should be continuous across all monitors.

Special Charts Aid the Design and Fabrication of Extruded Rubber Products

By **G. WILLIAM BECK**
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Division

Many rubber products, some of them having complex cross sections, are fabricated by the extrusion process. Although the process is basically simple, many factors contribute to the overall feasibility of extruding a specific product. Engineers at the Inland Manufacturing Division have devised *extrudability charts* to serve as guides in planning extrusions. These charts relate the factors affecting extrudability and show what limitations are placed on the possibility of extruding a product when one or more of these factors is constant. Inland engineers also developed a *maximum-minimum layout chart,* which is used for comparing production pieces with tolerance specifications. The layouts simplify the job of checking the many dimensions present in a complex cross section.

Answering the question: can the part be extruded?

Rubber products are found in many applications where abusive action, such as repeated impact, continuous flexing, vibration, abrasion, and exposure to heat, oil, and chemicals, might occur. Many of the rubber products used have complex cross sections, some of which can be fabricated best by extrusion.

Briefly, the process of extrusion involves a rotating tuber screw which forces a rubber compound through an extruding die having an aperture shaped to produce the desired cross section[1].

Many Factors Affect Extrudability

The basic idea behind the extrusion process is simple, but there are many factors which must be considered before deciding to extrude a specific rubber product. The major factors governing the successful extrusion of a product can be integrated into the term *extrudability.* The extrudability of a product is the degree of perfection to which it can be extruded. The important factors determining the extrudability of a given product are:

- Variation in cross section thickness and complexity of shape
- Length of uncured piece to be handled
- Physical properties and kind of compound to be used for the product.

Cross Section

A cross section having uniform thickness can be extruded in softer material than can a cross section that varies from thick to thin. If a section is irregular in shape, support of the section during cure might be necessary.

Length

Thin cross sections cannot be handled in straight lengths over 60 in. and still be held to close tolerances. Uniform tolerances can be held over the entire length of the extrusion if the design of the cross section is such that the product can be coiled during cure.

Compound

In general, closer tolerances can be held and thinner cross sections fabricated when using hard compounds than when using soft compounds. Also, compounds with higher tensile strength require greater tolerances and thicker cross sections than do low tensile strength compounds.

Crude natural rubber, GR-S, neoprene, Buna-N (acrylonitrile—oil resistant), butyl, and silicone materials all can be compounded to extrude a variety of satisfactory cross sections. Because of the basic physical characteristics of natural rubber and the various synthetic polymers, it is more practical to obtain tensile strengths above 2,000 psi with natural rubber and neoprene than with the other synthetics.

The maximum tensile strength obtainable with silicone is in the range of 700 psi to 1,000 psi.

Charts Relate Major Factors Affecting Extrudability

It is difficult to generalize about the effect of the many factors upon the extrusion of rubber products. However, Inland Manufacturing Division engineers have related several of these factors in chart form as guides in planning extrusion products. Known as *extrudability charts,* they can be used in several ways. If one of the factors collated by the charts is given for a specific extrusion, the charts reveal what limitations that factor places on the nature of the extrusion. If more than one factor is given, the charts show how the relationship of the factors will

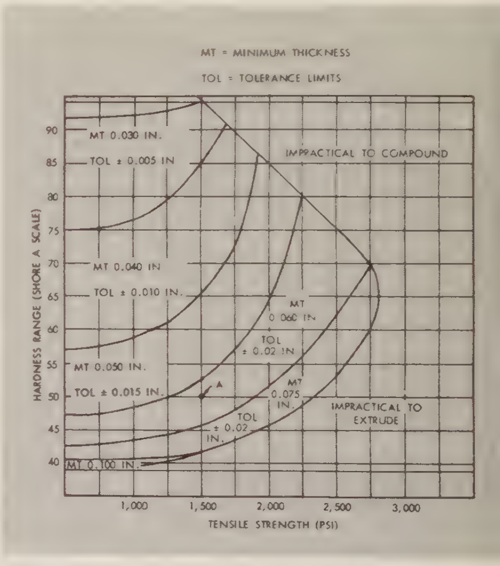


Fig. 1—The extrudability chart shown here relates hardness, tensile strength, tolerances, and minimum thickness for extruded rubber products of *uniform thin* cross sections. The vertical scale represents the hardness range in units determined by the Shore A durometer. The horizontal scale represents tensile strength in psi. The areas enclosed by the curved lines are the limits for the specifications designated within the areas (MT = minimum thickness; TOL = tolerance limits). If any of the factors on the chart are given for a product, the extrudability of the product can be found. For example, if a material must meet the specifications of 50-Shore A hardness, 1,500-psi tensile strength (point *A* on the chart), the product can be extruded with a minimum thickness of 0.060 in., and with a thickness tolerance of plus or minus 0.020 in. If tensile strength and hardness specifications fall outside the longest curve, the product is impractical to extrude.

affect the nature of the extrusion.

One extrudability chart relates hardness, tensile strength, and tolerance limits to the minimum practical *uniform* thickness that can be extruded satisfactorily (Fig. 1). Hardness of rubber compounds is measured by a *Shore A durometer* and expressed in Shore A units.

As an example of how this chart is used, a designer may know from experience that a rubber compound of a certain hardness and tensile strength should be used for a product. He can find these two values on the chart and then determine the minimum practical thickness that can be extruded and the tolerances that apply. Similarly, if the designer knows that the product requires a certain uniform thickness, the chart will indicate the hardness and tensile strength values for a material suitable for extruding.

A second extrudability chart relates hardness, tensile strength, and tolerance in extrusions with *non-uniform* cross sections that have a great variation in section thickness (Fig. 2).

In examining the second chart, two significant facts are of interest. First, it shows that the absolute minimum hardness for extrusion in non-uniform thin sections is higher—45 Shore A—than for extrusions of uniform thickness—37 Shore A (Fig. 1). The minimum hardness of 45 Shore A would be covered by a specification of 50 plus or minus 5 Shore A, and is interpreted to mean that 50 is the minimum hardness that should be specified. This condition exists because of the higher swell characteristics of softer materials and the difficulty encountered in attempting to build an extruding die that will produce thin sections immediately adjacent to thick sections.

The second significant fact of interest is that the closer tolerances indicated for higher hardness and relatively lower tensile materials are in line with the thinner extrusions permissible in these same physical ranges (Fig. 1). This relationship exists because of the lower swell characteristics of materials in these hardness and tensile ranges.

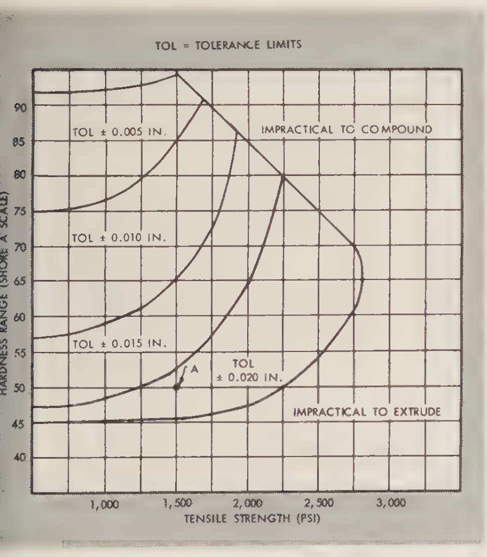


Fig. 2—The extrudability chart shown here is similar to that in Fig. 1, with the exception that this chart relates hardness, tensile strength, and tolerances to rubber products with *non-uniform* cross sections that vary from thick to thin. This chart can be used to find the tolerance for an extruded cross section of given hardness and tensile strength. For example, if the material has the specifications of 50-Shore A hardness, 1,500-psi tensile strength (point *A* on the chart), it can be extruded with a tolerance of plus or minus 0.020 in.

The application of the second extrudability chart is similar to the first chart. If a set of physical requirements for the material is given, a practical extruding tolerance can be determined. If, on the other hand, the product application demands close tolerances, the chart can be used as a guide to determine a specification for hardness and tensile strength of the extruded material.

Reliability Proved

It should be emphasized that the two extrudability charts are intended only as guides to the designer. It is probable that many production applications of extrusions violate the limits shown on the charts. But, more than likely, a higher cost is reflected in these parts because of higher scrap allowance, higher handling costs, or higher material costs resulting from the use of specialized compounds.

The reliability of the charts can be demonstrated by an example of an application to a rubber product for automotive use. The part was a rear axle bumper of a constant cross section, and its design suggested the use of the extrusion process for fabrication. The specifications called for the material to have a 50-Shore A hardness and a 2,400-psi tensile strength. Referring to the extrudability chart (Fig. 1), it was observed that the specifications placed the material just outside the range for practical extrusion. Since these requirements indicated a borderline situation, extensive test extrusions were made to prove the reliability of the chart. The tests showed that the extruded part had poor surface finish and could not meet dimensional tolerances (Fig. 3). Thus, the part could not be extruded satisfactorily, which bore out the indications of the chart. In this case, however, further tests were made with a material having different specifications of 50-Shore A and 2,000-psi, which was within the range of extrudability shown by the chart. It was determined that this material was satisfactory and the rubber bumper could be extruded when using a material meeting a specification within acceptable extrudability limits.

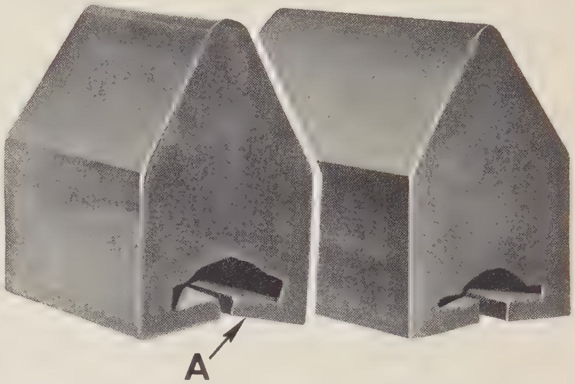
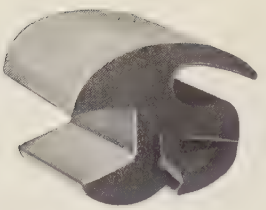


Fig. 3—A comparison between similar extrusions which differ only in tensile strength shows the reliability of the extrudability charts. The rear axle bumper on the left was extruded from high tensile strength stock which fell in the "impractical to extrude" range on the extrudability chart. The bumper on the right was extruded from a lower tensile strength stock which fell within the extrudability limits of the chart. Note the surface finish on the part having higher tensile strength, which shows an inability to meet dimensional requirements in the area of the attaching lugs *A*.

Special Drawings Check Complex Cross Sections

The need for observing tolerances when extruding a product requires a method for checking the specifications of the extrusion during its fabrication. This is not a difficult problem when a simple cross section is being made, such as a tube where the inner or outer diameters and wall thickness are dimensioned and appropriate tolerances are applied. However, a nearly impossible checking problem would be created if tolerances were applied to each dimension on a complicated cross section, such as an automotive



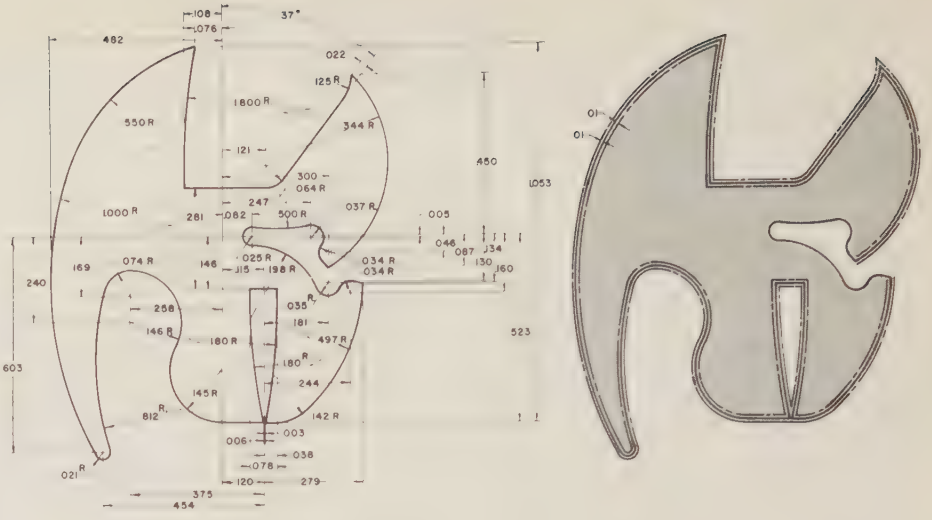
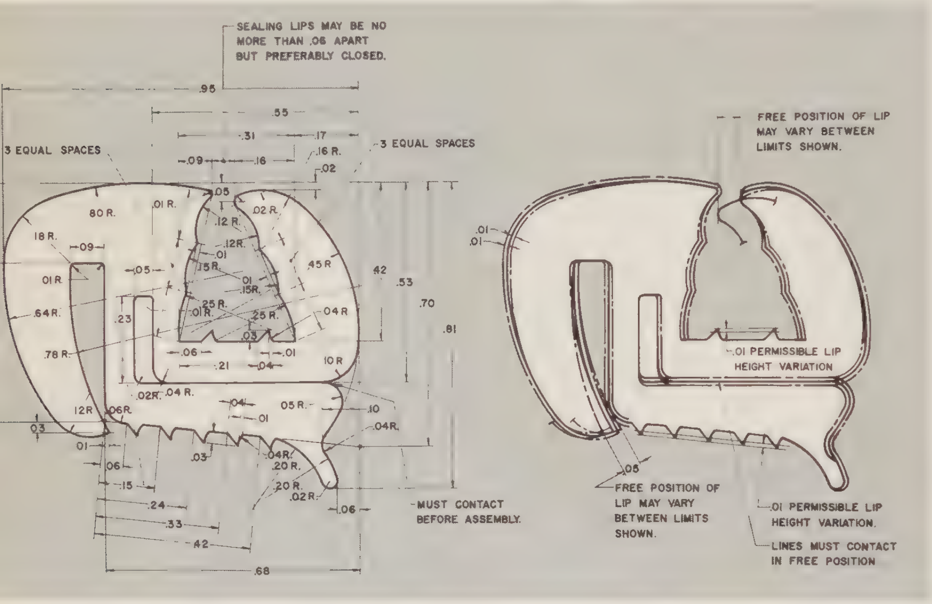


Fig. 4—The automotive backlight, or rear window, gasket shown above was fabricated by the extrusion process. The view at the near right indicates the problem of checking tolerances on the many dimensions of complex cross sections such as this. Inland Manufacturing Division engineers, therefore, developed a maximum-minimum layout chart (far right), for use during the fabrication of complex extrusions. On this layout, the solid outline represents the mean dimensions of the part, and the two broken outlines represent the tolerance limits for this specific product. By comparing the maximum-minimum layout chart with a shadowgraph projection of a fabricated cross section, the cross section can be checked for tolerances.



SEALING LIPS MAY BE NO MORE THAN .06 APART BUT PREFERABLY CLOSED.
.95
.55
.31
.17
3 EQUAL SPACES
.16 R.
3 EQUAL SPACES
.09
.16
.02
.05
80 R.
.01 R.
.12 R
.02 R.
18 R.
.09
.12R.
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01 R.
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MUST CONTACT BEFORE ASSEMBLY.
FREE POSITION OF LIP MAY VARY BETWEEN LIMITS SHOWN.
.01
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FREE POSITION OF LIP MAY VARY BETWEEN LIMITS SHOWN.
.01 PERMISSIBLE LIP HEIGHT VARIATION.
LINES MUST CONTACT IN FREE POSITION

Fig. 5—A variation of the maximum-minimum layout chart was used to check the tolerances of a windshield weatherstrip cross section. This product had two sealing lips which were difficult to hold to close tolerances while extruding. Therefore, the relative positions of the lips were allowed to vary, more than other dimensions, which were held to close tolerances of 0.010 in.

backlight, or rear window, gasket.

To simplify the problem of checking complicated cross sections, Inland Manufacturing Division engineers have devised a *maximum-minimum layout chart* (Fig. 4). This chart is a drawn outline of the mean cross section of the extrusion to be checked, with tolerances being applied to the chart. The drawing can be made to a large scale, such as a 10 to 1 scale, and a shadowgraph projection of the cross section being checked can be made at the same scale and compared directly to the maximum-minimum layout chart. Such a comparison reveals whether the extrusion falls within the tolerances allowed. This has proven to be a very practical method of checking any complex cross section when the projected section can be shown on commercially available projection equipment.

A variation of this method has been applied to a windshield weatherstrip cross section (Fig. 5). The specifications for this product called for a 53-Shore A, 1,500-psi compound, which, according to the extrudability chart, called for a tolerance of plus or minus 0.020 in. The particular application of this product, however, required closer tolerances in certain areas of the cross section. The solution to the problem was a compromise which specified plus or minus 0.010 in. tolerance on the mean outline, but permitted an additional variation in the relative position of the sealing lips, which was difficult to control during extrusion. In this case, checks on the sealing lips were made independently of each other using as the base line the bottom of the channel between the lips.

Summary

The extrudability and maximum-minimum layout charts are helpful aids in the product design and production phases of extruded products. The charts have resulted from much experience with extruded products, and are constructed around basic rules in extrusion work.

Although these rules serve as efficient guides to product design, they by no means limit the variety of applications and shapes that can be considered for extrusion.

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A Discussion of V-8 Engine Intake Manifold Design

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As part of the induction system of the internal combustion engine, the intake manifold has an important function in the carburetion of fuel. It is the intake manifold which receives the air and fuel mixture from the carburetor and delivers it to the cylinders. Intake manifold design has been directed toward the goal of insuring equal distribution of a mixture which has uniform physical and chemical qualities. Such a distribution provides the most efficient use of engine power and the best possible fuel economy.

Split manifold results in better fuel distribution

THE induction system of an overhead valve, V-8 engine includes the air cleaner, carburetor, intake manifold, cylinder head passages, valves, and combustion chambers.

The function of the intake manifold (Fig. 1) is to receive a mixture of fuel and air from the carburetor and deliver it to the eight cylinder head passages in equal quantity and quality, physically and chemically, so that the engine will consume it readily.

Designing the Intake Manifold

The design of the intake manifold of the gasoline engine presents two basic problems:

- The manifold must deliver equal quantities of fuel and air mixture to the cylinders
- The mixture must possess the same chemical and physical characteristics.

In other words, the qualitative and quantitative distribution of fuel and air mixture to each cylinder must be equal or near equal, so that the charge of all cylinders does not need to be enriched just to satisfy the lean ones.

The mixture delivered by the carburetor to the manifold is not a gas but consists of liquid particles suspended in the moving air. These particles are in the process of vaporizing, and, since this vaporization takes time, they travel the greater part of the manifold as a mist. The condition of the mixture when it leaves the manifold depends upon the amount of heat added to it, the velocity of flow, and the design of the manifold itself.

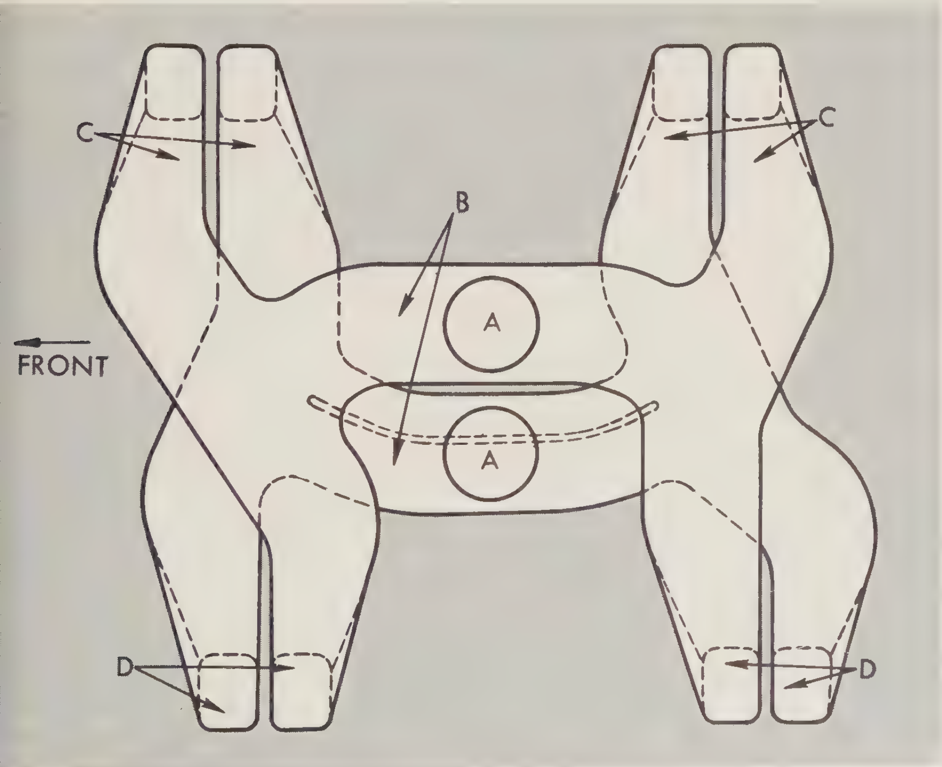


Fig. 1—A simple eight cylinder intake manifold consists of a riser *A* to carry the fuel and air mixture from the carburetor to the header *B*. The header, or runner, then carries the mixture to the passages (branches or legs) *C*, which deliver the mixture to the cylinders through the cylinder head ports *D*. A split intake manifold, which is usually found on V-8 engines, has two risers and headers, each set of which has its own passages and serves four cylinders. The reason for splitting the manifold is to eliminate charging more than one cylinder from the same passage at one time.

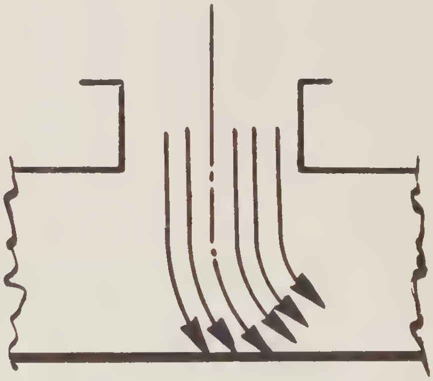


Fig. 2—A flat floor in the intake manifold provides a thin spread of fuel which is vaporized easily. The sharp corners loosen fuel film from the walls of the manifold and place the fuel back into the mixture flow stream. Rounded corners (Fig. 3) encourage a film of fuel to remain on the manifold surfaces.

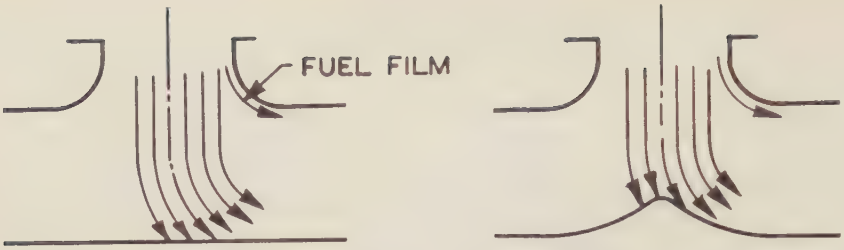


Fig. 3—Streamlining the intake manifold surfaces greatly affects the efficiency of its performance. If the manifold is streamlined so that the cross sectional area is increased (left), the velocity of the mixture is decreased and fuel precipitation increased. If the cross sectional area is not increased by the streamlining (right), the fuel tends to travel in one direction, since the throttle valve delivers the mixture unevenly. Streamlining is valuable only where the mixture flow is in one direction, such as in the legs of an in-line, L-head, intake manifold.

Velocities in the Manifold

When the cross sectional area of the manifold is too large, the velocity of the mixture in the manifold drops below a critical point where droplets of fuel begin to settle on the manifold walls. This changes the proportion of the fuel and air mixture metered by the carburetor. Thus, for ideal starting and idling conditions, the manifold should be of small cross sectional area.

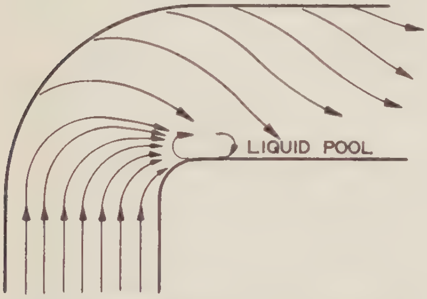


Fig. 4—A pressure differential in the mixture flow at sharp bends in the manifold results in the formation of a pool of fuel on the surface just beyond the smaller radius. Although the fuel continues to move with the mixture, the pool is replenished by additional particles forced into the low pressure area from the high pressure area at the larger radius.

Since the engine, however, consumes about nine times more air at maximum speed than at idle, the manifold cross sectional area should be large for ideal power conditions.

Thus, it can be seen that manifold design is a compromise, since the cross sectional area must provide reasonable idle and good maximum power.

Manifold surface roughness tends to promote fuel deposition by decreasing the velocity of the periphery of the mixture, even though the center portion of the mixture remains at high velocities and fuel remains in suspension there. The minimum velocity of air required to hold the fuel particles in suspension in the manifold riser has been found to be about 50 ft per sec at 1,000 rpm.

Shape of the Manifold

The manifold is made with a horizontal, flat floor so that any deposited liquid fuel spreads thinly and vaporizes easily (Fig. 2). Smooth surfaces reduce the tendency of fuel to collect and reduce the thickness of the film. Dams or guides on the floor of the manifold sometimes are used to direct liquid fuel to certain cylinders.

Since the riser is perpendicular to the horizontal floor, there is no tendency for the fuel to flow more to one branch than the other, or for the throttle valve to send the mixture in a favored direction.

Any streamlining of the manifold that increases cross sectional area tends to decrease velocity and increase fuel precipitation (Fig. 3). Sharp corners cause the film of fuel to tear loose from the wall and re-enter the stream. Streamlining without increasing the cross sectional area tends to send the fuel more in one direction than the other, since the throttle valve directs the mixture in a favored direction. Streamlining is of value where flow is in one direction only, such as in the legs of in-line, L-head, intake manifolds.

Flow at an Elbow

Bends in the manifold tend to increase deposition of fuel. Flow of fuel and air mixture at an elbow results in higher pressures at the outside wall (Fig. 4). This pressure difference causes flow from the outer radius to the inner radius of the elbow, and a pool of liquid fuel tends to accumulate on the manifold wall beyond the inner radius. Although the collected fuel continues to flow downstream, the pool is maintained by the deposition of

Fig. 5—The development of V-8 intake manifolds in the past 30 years reveals how an accumulation of design ideas and experiments have resulted in the present day manifold.

A V-8 manifold arrangement (a), patented in 1927, had two sets of intake ports, each supplying four cylinders. In each set, two center cylinders on one bank were connected to two outer cylinders on the other bank. The firing order was such that no two successively firing cylinders drew charges from the same set of ports. Thus, each cylinder was affected only slightly by suction from any other cylinder. This system was highly conducive to uniform distribution.

A patented idea of deflectors designed into a manifold (b) in an effort to obtain equal distribution was another early idea. It was difficult to obtain equal distribution in this manner, however, over the entire speed range.

In 1935, a V-8 manifold arrangement (c) was developed which was an adaptation from an earlier successful in-line engine manifold. The manifold was comprised of 90° corner bends, flat walls, and horizontal passages. The fuel and air mixture was directed against a flat wall at every bend, where fuel particles were broken up. The flat, horizontal floor caused the liquid fuel to spread thinly for easy vaporization, and the fuel flow did not favor any particular cylinder. Overhanging edges *A* prevented liquid fuel from flowing around the wall of the bend and caused the fuel droplets to fall into the air stream. Every surface along the route was lower than the previous one, so that any fuel deposited on the surfaces would end up eventually in the cylinder instead of forming puddles in the manifold. Many of these ideas are incorporated in present day manifolds.

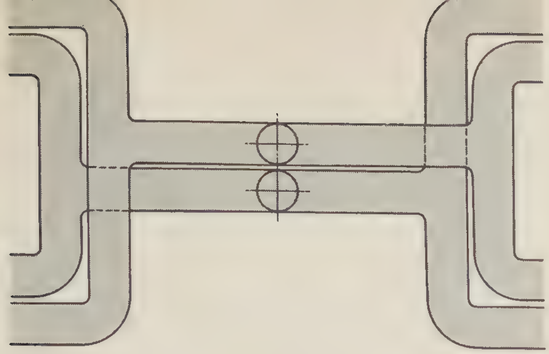
Also in 1935, a stamped manifold (d) of somewhat simpler arrangement appeared. The main headers ran fore and aft, the same as most present V-8 manifolds. Also significant in this manifold was the gradual reduction of cross sectional area. This caused mixture velocities to increase as they neared the outlet of the manifold.

By 1950, the ideas of equal length runners and passages of symmetrical shape to equalize distribution were introduced. The Pontiac V-8 manifold (e) illustrates this configuration. The top intake core supplied mixture to cylinders *2*, *3*, *5*, and *8*, and the lower core supplied cylinders *1*, *4*, *6*, and *7*. Since the firing order (f) is *1*, *8*, *4*, *3*, *6*, *5*, *7*, *2*, the two sets of passages alternated in supplying the cylinders.

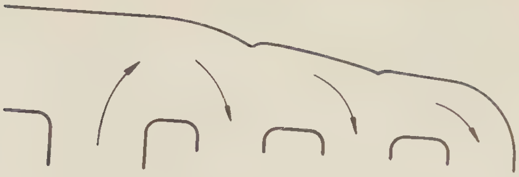
In passages *1* and *4*, which are part of the same set, the intake valve of cylinder *1* opened at 22° before top dead center (f). The intake valve of cylinder *4* opened 180° later, and both valves were open together until the valve of cylinder *1* closed at 67° past bottom dead center. Valve *4* remained open alone for the next 91°, and the passage of mixture into cylinder *4* was uninterrupted during this time. If the passages were not split, but drew from a common system, there would be no uninterrupted period. As many as three cylinders would be supplied mixture at one time instead of two.

Prior to production of this kind of manifold by Pontiac in 1955, two other types were investigated. One had the disadvantage of unequal lengths of passages and unsymmetrical shape (g), which favored one cylinder over another. Another design considered was one of individual passages from a common riser (h). This did not utilize the divided principle.

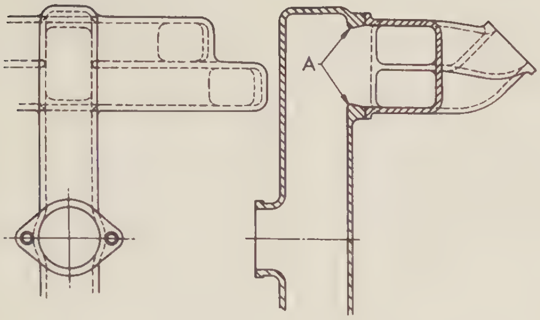
a



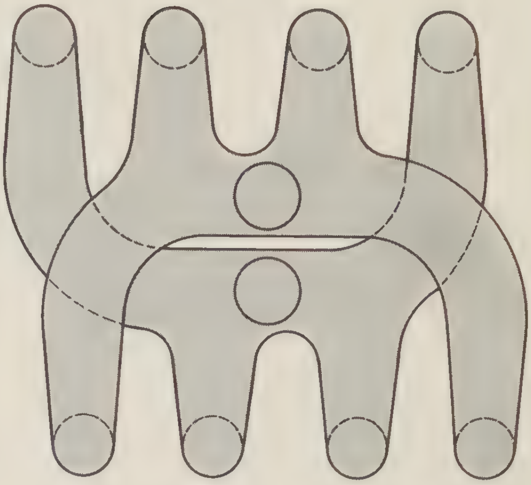
b



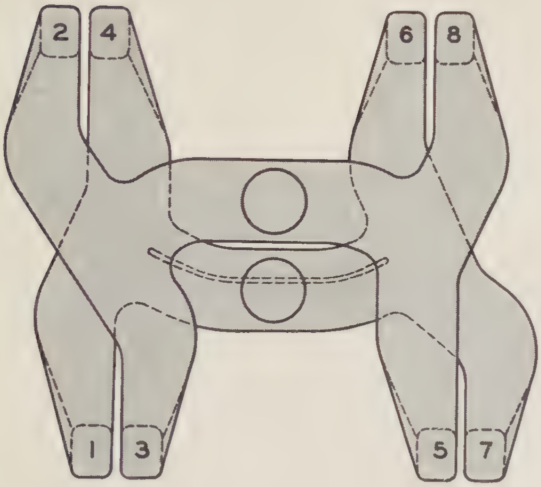
c



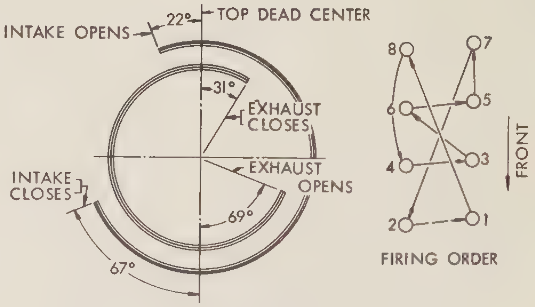
d



e

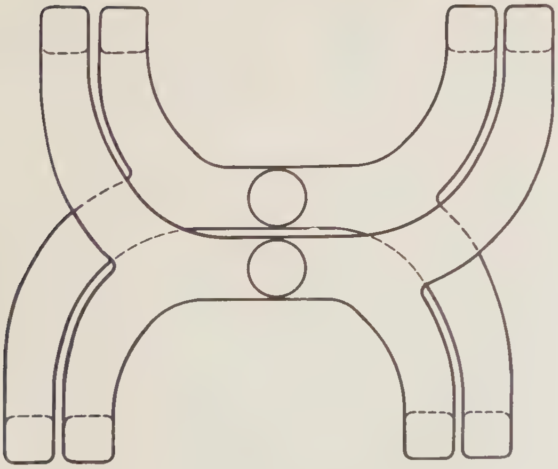


f

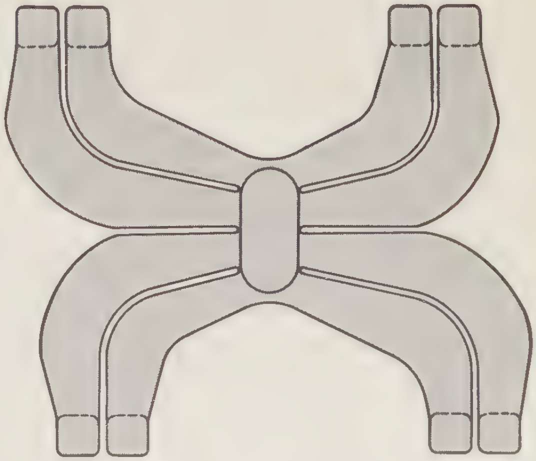


CRANKSHAFT TIMING DIAGRAM

g



h



suspended fuel particles that are prevented from striking and clinging to the outer wall by the flow towards the low pressure area.

Heating the Mixture

When a cold engine is started, excess fuel is required to provide a combustible air and fuel mixture because only the lighter ends of the fuel vaporize. Sufficient heat should be applied in the manifold to insure complete vaporization by the time the mixture is in the combustion chamber and the piston has completed its compression stroke. If the manifold were heated sufficiently to vaporize all the fuel, distribution difficulties would be eliminated, but the higher mixture temperature would decrease volumetric efficiency and power output.

A mixture temperature of about 100°F is required to vaporize gasoline completely. The mixture temperature at wide open throttle of most automobile engines is about 100°F. Heat usually is applied to the manifold at the riser or around the tee near the riser. The application of heat is controlled thermostatically so that maximum heating occurs under warm-up conditions. Fuel particles hit the hot surface and are broken up and partly vaporized.

Forming small fuel particles in the manifold is necessary, since the volume of a spherical particle decreases as the cube of the diameter, and the surface exposed to vaporization decreases only as the square. Thus, the total surface exposed increases rapidly as the particles become smaller.

Exhaust heat is used more often for heating manifold hot spots than coolant heat. Some British automobiles employ coolant heated manifolds because they use a hemispherical combustion chamber with intake and exhaust ports on opposite sides of the engine. With this type of arrangement, it is difficult to use exhaust heat effectively.

Development of the V-8 Intake Manifold

One of the most significant steps in the development of better carburetion and manifolding was the introduction of the double (split intake) manifold, in which the intake ports were divided into two sets, each set being supplied by its own carburetor. The sets were arranged so that the engine never drew from the same set twice in succession.

It was long recognized that when using a simple manifold, one intake valve was still open when the next began to open, and flow in one part was interrupted by the beginning of flow through the next. So, as early as 1913, it was suggested that two carburetors be used to supply two sets of ports so that this interruption could be minimized. This led to the development of the dual, or two-barrel, carburetor and manifold, which Pontiac first used in 1940.

The development of V-8 intake manifolds gives a good indication of the thinking of designers in the past 30 years (Fig. 5).

Present Manifolds Based Upon Past Design Experience

The present version of the V-8 intake manifold makes use of design knowledge gained through the years. The Pontiac two-barrel intake manifold and four-barrel manifold are of the same basic design. The triple two-barrel intake manifold also is essentially the same, except

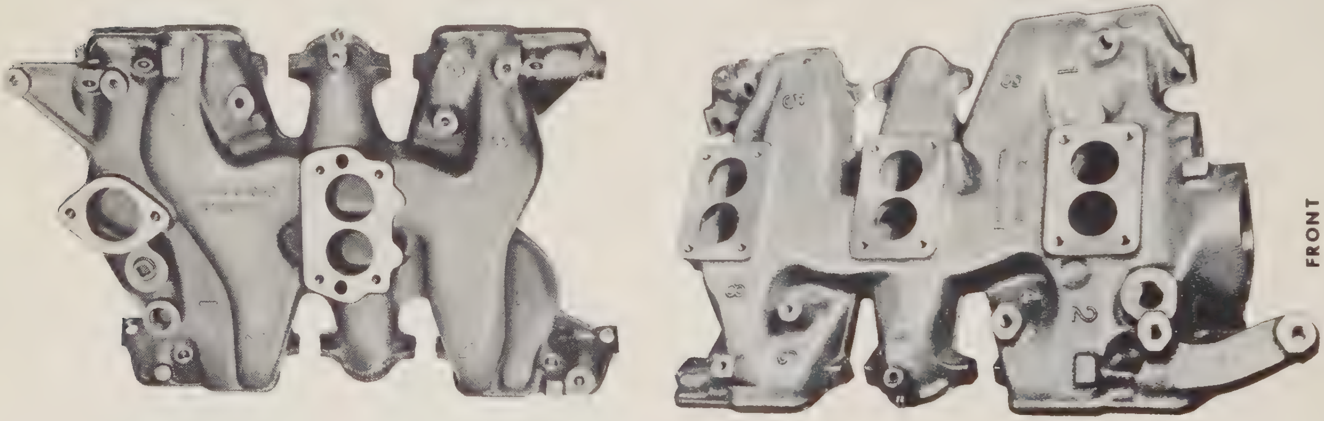


Fig. 6—Two types of intake manifolds used on Pontiac passenger cars are illustrated. In the two-barrel intake manifold (left), each of the vertical riser holes leads down into its own header. The headers run fore and aft and bend slightly to enter the branches, or legs, at right angles. Each of the branches runs transversely and connects to two cylinder head ports. These fuel and air mixture passages are practically equal in length and symmetrical in shape.

This manifold illustrates the 1957 design which provided two $\frac{15}{32}$-in. holes in the carburetor pad to carry hot exhaust gases to the carburetor flange to prevent icing of the throttle. These holes were eliminated in 1958, since the de-icer additives in gasolines made carburetor flange heating unnecessary.

Directly under the risers and headers and running transversely is an exhaust gas passage. Exhaust gases pass through this passage and help vaporize the fuel. At the right extreme end of this exhaust crossover is a $\frac{1}{4}$-in. hole into which the carburetor choke heat tube is inserted. At the right rear and left rear of the manifold are pads covering water jacket holes in the cylinder head.

Running transversely across the front is the water crossover port. Water from the cylinder heads enters this port from each end and is led to the radiator by way of the outlet tube in the center. To the left of the water outlet hole are two tapped holes which accommodate the heater hose fitting and the water temperature unit. At the right front are two generator mounting bosses, and four inches behind them is an air conditioning compressor brace boss. At the right rear are two bosses for securing the coil bracket. At the left rear is a boss for securing the throttle control bracket. The manifold is secured to the head with eight screws and four studs and nuts, the studs being used at the center, two to each head.

The triple two-barrel manifold (right) has its water outlet hole and water temperature unit tap further forward than the two and four-barrel manifolds and positioned horizontally to clear the front carburetor. The heater hose fitting boss is to the right of the front carburetor for the same reason, and the generator mounting bosses are of different design.

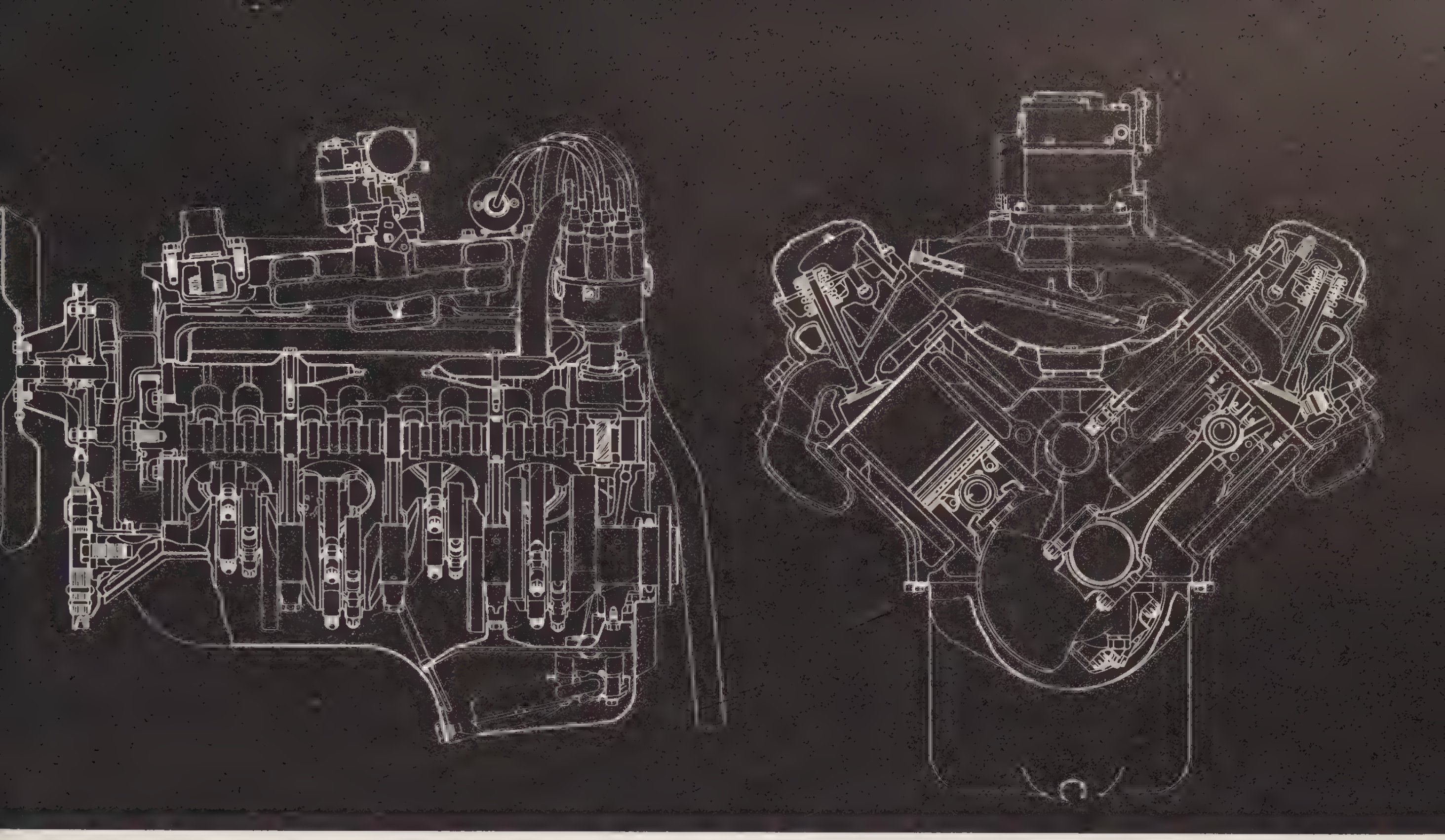


Fig. 7—A longitudinal cross section of the Pontiac engine (left) shows the carburetor and fuel and air passages angled at 5° 30′ with respect to the crankshaft centerline. When the power plant is installed in the chassis at an angle of 5° 30′ in the opposite direction, the carburetor and passages are horizontal. With this arrangement any liquid fuel deposited on the floor of the manifold header passage will not flow forward or backward into any one particular cylinder. Instead, it will flatten out into a thin film which is easily vaporized and taken equally to all cylinders with the air.

On the exhaust crossover port under the header, the top wall is heated. When fuel from the carburetor strikes this wall, it is heated and at least partially vaporized. A section through the right hand riser hole would show the right hand header to be above the one shown in the figure, in line with the sections of the transverse branches shown. A cross section of the water crossover and water outlet fitting is shown at the front of the engine. A front view transverse cross section of the engine (right) shows a section of the branch, or leg, of the air passage leading to the head. Shown at the left in this cross sectional view are the center exhaust ports of the head. When the engine is cold and the heat control valve (not shown) in the exhaust manifold on the left side is closed, exhaust gases cannot go to the left, but go right, through the intake manifold, through a similar head passage, and out to the other exhaust manifold. When the thermostatically controlled valve in the exhaust manifold is heated sufficiently to open, exhaust gases from the cylinder heads pass directly into the exhaust manifold, but enough "surge" gases pass through the intake manifold to maintain desired pre-heat conditions. Also shown is the choke heat tube in the intake manifold. Underhood air enters this tube at the lower end, passes through the tube where it is heated, passes into the carburetor choke thermostat unit through another tube, and from there is drawn into the carburetor. The heated thermostat in the choke unit opens the choke valve of the carburetor as the engine warms up. A twisted steel strip in the choke heat tube causes the air to spiral and pick up more heat than it ordinarily would.

for provisions made to accommodate the three, two-barrel carburetors (Fig. 6).

Another design consideration based upon past experience deals with the proper placement of the manifold on the engine (Fig. 7). Proper placement insures the functional efficiency of the manifold and also allows the best heating benefits to be gained from the exhaust system.

Conclusion

The desired features in a carburetor-type intake manifold have been found to be:

- Equal length and similar passages to all cylinders
- Adequate provision for mechanical mixing of fuel and air
- Provision for heating the mixture
- High manifold velocities consistent with good volumetric efficiency
- Smooth interior walls
- No enlargement of cross sectional area.

Incorporating these features, a well designed intake manifold results in good economy, equal power at all cylinders, and good engine flexibility.

Bibliography

Related literature in this field includes the following:

LICHTY, LESTER C., *Internal Combustion Engines* (New York: McGraw-Hill Book Co., Inc., 1951).

LUDVIGSON, KARL, "Whence Come the Horses?" Part I, *Sports Car Illustrated*, Vol. 3, No. 1 (July 1957), pp. 14-17, 47.

POPE, A. W., JR., *The Induction System of the Internal Combustion Engine* (Waukesha, Wisconsin: Waukesha Motor Company, 1954).

REPRINT AVAILABLE

In a recent issue of *The Annals of the American Academy of Political and Social Sciences*, Charles A. Chayne, vice president in charge of the GM Engineering Staff, discussed the topic, "Automotive Design Contributions to Highway Safety." Engineering educators interested in having a reprint of this article may write to Educational Relations Section, Public Relations Staff, GM Technical Center, P.O. Box 177, North End Station, Detroit 2, Michigan.

Mechanization Now Being Used in U.S. Patent Office Searches

By **ALBERT M. HEITER**
Patent Section
Detroit Office

Machine searching shows promise after trial with group of chemical patents

When a patent application is filed in the United States Patent Office, the application includes, in addition to the description of the invention, claims which, to the best of the knowledge of the applicant and the patent attorney who drafted the application, attempt to define the invention which it is considered that the applicant has made.

A U.S. patent can only be granted on a *new* process, machine, article of manufacture, or composition of matter. Therefore, the Patent Office must make an examination of the application which requires that a search be made through prior patents and publications which it has on file to determine whether the applicant is the first to make the invention defined by each claim, as well as whether the subject matter involves invention.

Those who have had occasion to make a complete patent search or to locate all the source material for a research project will appreciate the difficulty of finding all the relevant material in the vast volume of technical literature. Often the job is like the proverbial task of finding a needle in a haystack.

Search Among Thousands of Patents May Be Required

At the present time there are more than 2,850,000 U.S. patents, over 5,000,000 foreign patents, and an endless volume of printed technical publications. The U.S. Patent Office maintains a very excellent and complete system of patent classification having over 50,000 subclasses arranged in 307 main classes. However, many of these classes have not been revised for years and they contain large miscellaneous subclasses containing several hundred patents. With the staff available for this work, the Patent Office has not been able to eliminate the backlog of classification work and keep pace with today's rapidly expanding technology.

Thus, a complete manual search often may require that a thousand or several thousand patents and other items in the technical literature be examined to select the few patents that are most pertinent to the invention. While the Patent Office does a good job in making its examination, considering the magnitude of this task, important items are at times overlooked with the result that there cannot be complete assurance of the validity of the patents which are issued.

For many years the Classification Division of the Patent Office, while continuing its reclassification program for manual searching, has explored the possibility of using mechanical aids for improved searching. Study was made of the basic problems involved, of possible methods of coding, and of the adaptabilities of data selecting machines available. Then as a pilot program, a small group of related chemical patents was coded so that the disclosures could be placed on punched cards for automatic searching on punched card sorting machines.

This preliminary work created further interest and indicated the possibility of considerable savings to the Patent Office and the public through machine searching. As a result of this, Congress, in considering the Department of Commerce Patent Office budget request for the fiscal year of 1955, authorized the Department to make an aggressive and thorough investigation as to the possibility of mechanizing the searching operations. Then Commerce Secretary Sinclair Weeks asked Dr. Vannevar Bush to accept the chairmanship of a committee to study the problems involved and make recommendations to the Commerce Department. A committee of people eminently qualified with the problems of Patent Office classification and searching, with the problems of classification and coding suitable for machine searching, and with data processing machines, was formed. This committee consulted with about 30 U.S. firms actively engaged in the sale or development of machine data processing equipment. It also consulted with Government agencies such as the Department of the Census, which has considerable experience using machine data analyzing systems, and the National Bureau of Standards, which has an active research program on data processing machines. As a result of this study, Dr. Bush's committee recommended that the Patent Office should at once proceed toward placing machine searching of composition of matter patents on an operational basis.

Study Showed Machine Searching Could be Applied

Thus, the Patent Office established a Research and Development Group to carry out this program. The study of coding systems for chemical compounds was continued and resulted in the development of a coding system for steroid compounds. Although the coding system developed for the steroid compounds is not specifically applicable to other chemical compounds, the experience and knowledge gained in this development will aid in codifying other groups of chemical patents. The codification of non-chemical patents presents a more formidable intellectual problem, since the mechanical and electrical sciences and technologies do not have a uniform system of nomenclature. Thus, the possibility of devising a code language of precise, logically developed terms is now being studied.

After the 1,420 patents then found in twelve subclasses on steroid compounds were coded, the Patent Office employed machine searching in the examination of pending applications on steroid compounds. The examiner making a machine search is generally able to set the punched card sorting machine to select less than 50 cards representing the patents most pertinent to the application. This small group of patents is then carefully studied by the examiner to determine whether a patent should be granted. The initial experience indicates that machine searching is considerably faster and more accurate. The improved accuracy of a machine search may be attributed to the fact that the examiners can make a more

Notes About Inventions and Inventors

Contributed by
Patent Section
Detroit Office

complete study of the patents for coding than they customarily do during each manual search and the machine can quickly search a larger volume of patents and select only a small group of the most relevant patents.

The expansion of mechanical searching facilities to other fields will not only aid the Patent Office and inventors but also will assist scientists and engineers in development and research work by enabling them to locate quickly specific facts in the vast storehouse of technical information.

THE following is a general listing of patents granted in the names of General Motors employes during the period July 1, 1958 to September 30, 1958.

AC Spark Plug Division
Flint, Michigan

- **Wilfred A. Bychinsky,** (*B.S.E.E., 1930; M.S.E., 1931; and Ph.D., 1933, University of Michigan*) chief engineer, automotive products, and **Alfred Candelise,** (*Ph.D. in electrical-mechanical engineering, University of Naples, 1923*) staff engineer, Spark Plug Engineering Department, inventors in patent 2,840,628 for a spark plug.

- **Jesse E. Eshbaugh,** (*M.E., University of Cincinnati, 1923*) staff engineer, New Devices Department; **Thomas W. Lamar,** (*B.I.E., General Motors Institute, 1951*) project engineer — pneumatics group, Automotive Engineering Department; and **Werner F. Schultz,** (*B.E.E., University of Detroit, 1938*) development engineer, Automotive Engineering Department, inventors in patent 2,845,893 for a steering direction indicator.

- **Theo A. Bartlett,** (*B.E.E., The Ohio State University, 1931*) section head—experimental production, Defense Engineering Department, inventor in patent 2,849,679 for a voltmeter.

- **Jesse E. Eshbaugh*,** inventor in patent 2,849,796 for a dip stick.

Allison Division
Indianapolis, Indiana

- **Victor W. Peterson,** (*B.S.M.E., Rose Polytechnic Institute, 1939*) Advance Design and Development Section, and Herbert H. Schnepel, retired, inventors in patent 2,838,913 for an aircraft power system and clutch control therefor.

- **Arthur R. Mauck,** (*B.M.E., General Motors Institute, 1951, and American University, Washington, D.C., 1941*) in charge of special projects group, Turbo-Jet Engineering Department, and John M. Zorad, no longer with GM, inventors in patent 2,845,141 for an accessory oiling system.

- **Esten W. Spears, Jr.,** (*B.S.M.E., University of Kentucky, 1942*) senior project engineer, turbo-jets, inventor in patent 2,847,825 for a gas turbine thrust augmenter comprising water injection ring.

- **John R. Hayes,** (*General Motors Institute, 1944*) senior project engineer, Turbine Engine Engineering Department, inventor in patent 2,848,192 for a multipiece hollow turbine bucket.

- **Robert P. Atkinson,** (*B.S.M.E., Purdue University, 1935*) section chief, Advance Design and Development Section, and **Frederick W. Hoeltje,** (*B.S.M.E., Bradley University, 1940*) senior project engineer, Advance Design and Development Section, inventors in patent 2,848,284 for a bearing oil scavenger.

- **John B. Wheatley,** (*A.B.M.E., 1929, and M.E. in aeronautics, 1930, Stanford University*) assistant chief engineer, Advanced Design Engineering Department, inventor in patent 2,840,227 for a compressor air bleed-off valve.

- **Edmund M. Irwin,** (*B.S. in physics, Central Michigan College, 1938*) head, control electronics, Fuel Systems and Components Department; **Floyd J. Boyer,** (*B.S.M.E., Georgia Institute of Technology, 1940*) group project engineer, turbo-prop engine controls; **Arthur W. Gaubatz,** (*B.S., University of Wisconsin, 1920*) senior project engineer, Experimental Engineering Department; and **Robert J. Wente,** (*B.S.M.E., Purdue University, 1941*) head, advanced design power turbine controls, Aircraft Engine Engineering Department, inventors in patent 2,851,113 for a control system for a variable pitch propeller and its driving turbines.

***Inventors' names marked with an asterisk have biographical listings noted previously in this issue's Notes About Inventions and Inventors.**

- **John L. Goldthwaite,** (*B.S.C.E., Purdue University, 1921*) special assignment, Engineering Department, and Joseph L. Bonnano, not with GM, inventors in patent 2,853,638 for an inductor generator.

- **Robert M. Tuck,** (*B.M.E., General Motors Institute, 1947*) development engineer, Transmission Engineering Department, inventor in patent 2,853,891 for a control for automatic transmission.

Aeroproducts Operations
Allison Division
Vandalia, Ohio

- **Roy H. Brandes,** senior project engineer, Engineering Department, inventor in patent 2,850,105 for a propeller mechanism with means to vary the pitch change rate.

Brown-Lipe-Chapin Division
Syracuse, New York

- **Alfred R. Marcy, Jr.,** (*General Motors Institute, 1951*) senior product engineer—sheet metal parts, Engineering Department, and **Stanford Landell,** (*University of Pennsylvania*) works manager, inventors in patent 2,854,104 for a fabricated grille structure.

Buick Motor Division
Flint, Michigan

- **Dallas D. Danser**, draftsman, Engineering Department, inventor in patent 2,840,847 for a hinging arrangement.

- **Lloyd E. Muller**, (*B.S.M.E., University of Kansas, 1929*) director, Experimental Engineering Department, inventor in patent 2,847,819 for a reversible exhaust manifold system.

- **Joseph D. Turlay**, (*B.S.M.E., Oregon State College, 1928*) director, Power Plant Activities, inventor in patent 2,852,009 for a cooling liquid circulating system for engines.

Cadillac Motor Car Division
Detroit, Michigan

- **Daniel M. Adams**, (*Detroit Institute of Technology and University of Michigan*) staff engineer, Body and Sheet Metal Section, and Charles P. Roth, no longer with GM, inventors in patent 2,837,758 for a windshield wiper transmission.

- **Hugo H. Wendela**, (*B.S.Aero.E., Wayne State University, 1936*) assistant staff engineer, Engineering Department, inventor in patent 2,844,999 for a rear view mirror.

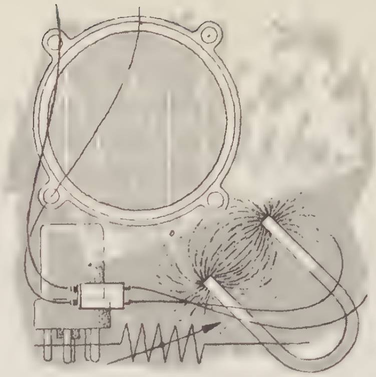
- **William E. Bell**, (*B.S.E.E., University of Kentucky*) senior project engineer, inventor in patent 2,845,614 for a signal device test circuit.

- **Ralph H. Johnson**, (*B.S.M.E., University of Washington, 1952*) senior project engineer—engines, inventor in patent 2,848,288 for a piston ring.

- **Edgar Haigh**, (*B.S.E., Halifax Technical College, Yorks, England, 1923*) staff engineer, Engine, Cooling, Fuel, and Exhaust Department, and Arthur H. Stahlhuth, retired, inventors in patent 2,850,314 for a bumper exhaust.

- **Chester J. Glowzinski**, senior project engineer—instruments, lights, and accessories, Engineering Department, inventor in patent 2,851,585 for an illuminated ash tray.

- **Harry F. Barr**, (*B.M.E., University of Detroit, 1929*) now chief engineer, Chevrolet Motor Division, and **Adelbert E. Kolbe**, (*University of Michigan*) assistant staff engineer in charge of advanced engine design, Research and Development Department, Chevrolet Motor Division, inventors in patent 2,853,062 for an engine structure.



- **Peter Zerhan, Jr.**, senior project engineer, inventor in patent 2,854,278 for a bumper exhaust.

Central Foundry Division
Saginaw, Michigan

- **William S. Hackett**, (*The Ohio State University*) research engineer, Experimental and Development Department, and **Donald J. Henry**, (*M.S., The Ohio State University, 1937*) assistant head, Metallurgical Engineering Department, GM Research Laboratories, inventors in patent 2,845,669 for a method of casting in shell molds.

Chevrolet Motor Division
Detroit, Michigan

- **Kai H. Hansen**, (*Lawrence Institute of Technology*) assistant director, Research and Development Department; Maurice Olley, retired; and **Robert Schilling**, (*M.E. degree, Technical University, Munich, Germany, 1922*) director, Research and Development Department, inventors in patent 2,848,248 for an anti-roll scheme.

- **Joseph F. Bertsch**, (*B.S.M.E., University of Cincinnati, 1948*) research engineer, Research and Development Department, and **Kai H. Hansen***, inventors in patent 2,848, 249 for an air suspension leveling system.

- **Hugh W. Larsen**, (*B.S.E.E., University of Minnesota, 1949*) senior project engineer, Noise and Vibration Laboratory, Proving Ground Section, GM Engineering Staff; **George H. Primeau**, (*Northern State Teachers College*) design engineer, Research and Development Department; and **William O. Robbins**, (*B.S.Auto.E., Syracuse University, 1936*) experimental development engineer, Chevrolet Proving Ground Engineering Department, inventors in patent 2,848,882 for a drive noise insulating means.

- **Ralph H. Merkle**, (*B.M.E., General Motors Institute, 1948*) senior experimental engineer, Engineering Department; **Shirrell C. Richey**, (*General Motors Institute, 1937*) now assistant chief engineer, Engineering Department, Buick Motor Division; and Cleo H. Key, no longer with GM, inventors in patent 2,849,074 for a battery retainer means.

- **Adelbert E. Kolbe**, (*University of Michigan*) assistant staff engineer in charge of advanced engine design, Research and Development Department, and **Earl W. Rohrbacher**, (*B.S.M.E., University of Utah, 1926*) design engineer, Engine Design Group, inventors in patent 2,849,858 for an exhaust system for engines.

- **William S. Wolfram**, (*B.S.Auto.E., University of Michigan, 1932*) assistant staff engineer, Research and Development Department, inventor in patents 2,852,910 and 2,852,952 for an exhaust manifold and an adjustable grip pulley, respectively.

- **Adelbert E. Kolbe***, inventor in patent 2,853,986 for a crankcase ventilation system.

- **Philip C. Bowser**, (*B.M.E., The Ohio State University*) now director, Research and Development Engineering Department, Buick Motor Division, and Maurice Olley*, inventors in patent 2,854,100 for a vibration damper.

- **Frank J. Winchell**, (*Purdue University*) staff engineer, Passenger Car Transmission Department, inventor in patent 2,854,300 for a transmission (thrust bearing).

Delco Products Division
Dayton, Ohio

- **Paul J. Long, Jr.**, (*B.S.M.E., University of Cincinnati, 1941*) section engineer, Engineering Department, and **Richard L. Nietert**, (*General Motors Institute, 1946*) now senior project engineer, Engineering Department, Cadillac Motor Car Division, inventors in patent 2,844,226 for a hydraulic shock absorber.

- **George W. Jackson**, (*B.S.M.E., Purdue University, 1937*) staff engineer, Automotive and Mechanical Products Department, inventor in patents 2,844,384 and 2,850,276 for a control apparatus for fluid suspension system and a hydropneumatic suspension unit, respectively.

- **John F. Pribonic,** (*B.S.M.E., Princeton University, 1947*) section engineer, Advance Automotive Design Department, inventor in patents 2,844,385 and 2,844,386 for a ride height control valve.
- **Harold E. Schultze,** project engineer, Engineering Department, inventor in patent 2,848,261 for a rod seal for a shock absorber.

Delco-Remy Division
Anderson, Indiana

- **Julius H. Bolles,** (*B.S. in physics, Ohio Wesleyan University, 1920*) director of sales and engineering, and **Lyman A. Rice,** (*B.S.E.E., University of Utah, 1935, and M.S.E., University of Michigan, 1936*) staff engineer, inventors in patent 2,840,768 for a tensioning device.
- **Brooks H. Short,** (*B.S.E.E., 1931, and M.S.E.E., 1934, Purdue University*) supervisor, engineering research, inventor in patents 2,842,334 and 2,845,608 for a control device and a turn signal system, respectively.
- **Lyman A. Rice*,** inventor in patents 2,842.634 and 2,847,530 for an electrical regulator and a centrifugal switch, respectively.
- **Harold J. Cromwell,** (*B.S.M.E., Purdue University, 1933*) senior research engineer; **Charles E. Buck,** (*B.S.E.E., Purdue University, 1935*) engineer—solenoids, Engineering Department; and **Argyle G. Lautzenhiser,** (*B.S.E.E., Tri-State College, 1940*) senior project engineer, AC Spark Plug Division, inventors in patent 2,842,680 for an electric switch.
- **Karl P. Shetterly,** assistant to the welding engineer, Process Department, inventor in patent 2,844,749 for a dynamo electric machine commutator connection.
- **Karl P. Shetterly*,** and **Charles D. Blagg,** foreman, process shop, Process Department, inventors in patent 2,845,693 for a method of manufacture of welded electrical terminals.
- **Brooks H. Short*,** and **Harry H. Freeman,** no longer with GM, inventors in patent 2,846,992 for an ignition system.
- **Brooks H. Short*,** and **Stanley E. Jacke,** no longer with GM, inventors in patent 2,847,489 for an ignition system.
- **Kenneth W. Young,** (*B.S.Chem.E., University of Illinois, 1941*) senior project engineer, Product Engineering Department, inventor in patent 2,849,548 for an electric switch.
- **Harold V. Elliott,** (*General Motors Institute, 1938*) senior project engineer, inventor in patent 2,849,549 for an electric switch.
- **Charles A. Nichols,** (*B.S.M.E., Carnegie Institute of Technology, 1923*) now technical assistant to the vice president in charge of GM Process Development Staff, and **George L. Weiser,** chief process engineer, Process Department, inventors in patent 2,850,795 for an apparatus for securing laminations to a shaft.

Delco Radio Division
Kokomo, Indiana

- **James H. Guyton,** (*B.S.E.E., 1934, and M.S.E.E., 1935, Washington University*) chief engineer—radio, Engineering Department, inventor in patents 2,843,744 and 2,854,582 for a transistor oscillator starting circuit.
- **William R. Kearney,** (*B.S.M.E., Purdue University, 1933*) senior project engineer, Mechanical Engineering Section, and **Manfred G. Wright,** (*B.S.M.E., Purdue University, 1938*) head, Mechanical Engineering Section, inventors in patent 2,848,899 for a manually loaded signal seeking tuner.
- **Clarence J. Votava,** (*B.S.E.E., Illinois Institute of Technology, 1943*) senior project engineer, Engineering Department, inventor in patent 2,851,605 for a control system for signal seeking tuner.
- **George M. Gaskill,** (*B.S. in physics, Franklin and Marshall College, 1951*) senior project engineer, Mechanical Engineering Section, Engineering Department, and **Manfred G. Wright*,** inventors in patents 2,851,887 and 2,852,944 for a combined signal seeking push button and manual tuner.

Detroit Diesel Engine Division
Detroit, Michigan

- **Charles H. Frick,** (*B.S., Iowa State College, 1934*) senior project engineer, Engineering Department, inventor in patent 2,845,915 for a fuel control mechanism.

These patent listings are informative only and are not intended to define the coverage which is determined by the claims of each one.

- **Roger D. Wellington,** (*B.S.M.E., University of Rochester, 1930*) director of test, Engineering Laboratory, inventor in patent 2,853,766 for a method of making rotary blower.

Diesel Equipment Division
Grand Rapids, Michigan

- **William J. Purchas, Jr.,** (*B.S.M.E., The Detroit Institute of Technology, 1933*) now chief engineer, Bearings Department, Transmission Operations, Allison Division, inventor in patent 2,840,063 for a hydraulic valve lifter.
- **Alfred H. Cobo,** special assignment, Manufacturing Facilities and Services Department, inventor in patent 2,845,914 for a valve lifter cylinder and method of making same.

Electro-Motive Division
La Grange, Illinois

- **Clarence H. Patrie,** (*B.S.M.E., University of Dayton, 1936*) senior designer, Research Department, and John Markestein, deceased, inventors in patent 2,843,057 for a railway vehicle suspension.
- **Thomas B. Dilworth,** assistant chief engineer, Engineering Department; **Max Ephraim, Jr.,** (*B.S.M.E., Illinois Institute of Technology, 1939*) locomotive section engineer, Engineering Department; and John T. Ialeggio, no longer with GM, inventors in patent 2,846,148 for an air heating system.
- **William F. Holin,** (*M.E., Konstanz, Germany*) senior project engineer, Engineering Department, inventor in patent 2,848,071 for a brake rigging.
- **Torsten O. Lillquist,** electrical research engineer, inventor in patent 2,848,262 for a wheel slide control for dynamic braking.
- **Robert L. Ten Eyck,** (*B.S.M.E., Purdue University, 1942*) parts development engineer, Engineering Department, inventor in patent 2,849,265 for a floating piston pin.
- **Brian M. Gallagher,** (*B.S.M.E., Worcester Polytechnic Institute, 1945*) senior designer, Research Department, inventor in patent 2,850,988 for a locomotive.

GM Engineering Staff
Detroit, Michigan

- **Lewis D. Burch,** (*B.S.M.E., Purdue University, 1923; George Washington Univer-*

sity; Akron Law School, and Wayne State University) patent attorney, Patent Section, Detroit Office, inventor in patent 2,838,955 for a vibration damper.

- **Albert J. Zupancic**, senior technician, Test Facilities Department, inventor in patent 2,841,131 for a fuel metering system.

- **Raymond J. Haefner**, (*B.M.E., General Motors Institute, 1950*) now with Rochester Products Division; **George P. Ransom**, (*B.S.M.E., University of Michigan, 1949*) section engineer, Power Development Group; and John Dolza, no longer with GM, inventors in patent 2,843,896 for a fuel distribution means.

- **George P. Ransom***, and **John Zimmerman**, (*Detroit City College*) senior design engineer, Power Development Group, inventors in patent 2,843,099 for a fuel metering mechanism.

- **Von D. Polhemus**, (*B.S.M.E., University of Cincinnati, 1933*) engineer in charge, Structure and Suspension Development Group, and **Max Ruegg**, (*M.E., Swiss Polytechnic, 1921*) assistant engineer in charge, Structure and Suspension Development Group, inventors in patent 2,845,279 for a vehicle torsion spring suspension.

- **Oliver K. Kelley**, (*B.S., Chicago Technical College, 1925, and Massachusetts Institute of Technology*) now chief engineer, Buick Motor Division; **Gilbert K. Hause**, engineer in charge, Transmission Development Group; and **Clifford C. Wrigley**, (*B.S.M.E., University of Colorado, 1936*) assistant engineer in charge, Transmission Development Group, inventors in patent 2,847,978 for a windshield wiper actuating mechanism.

Euclid Division
Cleveland, Ohio

- **Janis Mazzarins**, (*Technical University, Aachen, West Germany*) senior project engineer, Engineering Department, inventor in patent 2,837,380 for a track recoil mechanism.

Fabricast Division
Bedford, Indiana

- **Harold L. Benham**, (*B.S. in physics, Indiana University, 1951*) development engineer, Process Engineering Department, inventor in patent 2,851,752 for a high strength investment casting mold.

Fisher Body Division
Detroit, Michigan

- **Clarence P. McClelland**, (*University of Detroit*) senior project engineer, Design and Drafting Department, inventor in patent 2,840,844 for a windshield wiper transmission cable tensioning apparatus.

- **Bernard H. Keating**, body designer, Design and Drafting Department, and **Claude P. Sprunk**, (*General Motors Institute, 1941*) assistant engineer in charge, door group, Design and Drafting Department, Engineering Section, inventors in patent 2,841,418 for a sheet metal fastener for connecting a flexible drainage tube to a plate.

- **Eugene J. Fritz**, (*M.E., College of Mechanical Engineering, Esslingen, Germany, 1926*) engineer in charge, Tool Planning Department, inventor in patent 2,846,231 for a fastener means for vehicle gas tank.

- **Louis P. Garvey**, (*B.M.E., University of Detroit, 1939*) senior project engineer, Experimental and Development Department; **Harry A. Mackie**, (*B.S.M.E., and B.S.Aero.E., Louisiana State University*) now design engineer, Automobile Studio, Styling Staff; and **Clyde H. Schamel**, (*B.S.E.E., University of Notre Dame, 1927*) engineer in charge, Central Experimental and Development Department, inventors in patent 2,847,937 for an actuator mechanism.

- **James D. Leslie**, (*B.M.E., University of Detroit, 1939*) engineer in charge, Mechanical Department; **Clyde H. Schamel***; and **Claude S. Semar**, (*Detroit City College, University of Michigan, and Wayne State University*) senior project engineer, Experimental and Development Department, inventors in patent 2,848,218 for a window regulator.

- **Charles P. Simler**, project engineer, Physical Testing Laboratory, inventor in patent 2,850,278 for a tape reel.

- **William E. Sehn**, (*B.M.E., General Motors Institute, 1951*) assistant engineer in charge, Design and Drafting Department, inventor in patent 2,850,934 for a two headed bolt having predetermined shear strength.

- **Clyde H. Schamel***, inventor in patent 2,852,000 for a dual windshield wiper motor system.

- **Robert M. Fox**, (*B.M.E., General Motors Institute, 1950*) senior project engineer, Experimental and Development Department; **James D. Leslie***; and **Ellis J. Premo**, (*Chrysler Institute*) executive assistant chief engineer, Engineering Department, Chevrolet Motor Division, inventors in patent 2,852,997 for a vehicle ventilation system using shroud chambers.

Frigidaire Division
Dayton, Ohio

- **Verlos G. Sharpe**, (*B.S.M.E., Purdue University, 1948*) section engineer, Refrigerated Appliances Engineering Department, inventor in patents 2.841,459 and 2,844,111 for vertically adjustable refrigerator shelves and a refrigerating apparatus door control mechanism, respectively.

- **Ronal H. Whyte**, (*Sinclair College*) senior engineer — clothes dryers, Non-Refrigerated Appliances Engineering Department, inventor in patent 2,843,945 for a domestic appliance.

- **John Weibel, Jr.**, (*B.S.M.E., Louisiana State University, 1948, and M.S.M.E., Purdue University, 1950*) senior project engineer, Refrigerated Appliances Engineering Department, inventor in patent 2,844,302 for a refrigerating apparatus.

- **John H. Heidorn**, (*General Motors Institute, 1941*) project engineer, Research and Future Products Engineering Department, and Richard J. Becht, no longer with GM, inventors in patent 2,844,305 for a refrigerating apparatus.

- **Orson V. Saunders**, supervisor of major product line, Refrigerated Appliances Engineering Department, and **James A. Wallace**, (*Purdue University and University of Cincinnati*) project engineer, Refrigerated Appliances Engineering Department, inventors in patent 2,845,320 for a refrigerator cabinet construction.

- **Orson V. Saunders***, and **Milton G. Betz**, (*General Motors Institute, 1942*) senior project engineer, Refrigerated Appliances Engineering Department, inventors in patent 2,845,321 for a refrigerating apparatus.
- **Robert Galin**, (*B.S.M.E., Robert College, Istanbul, Turkey, 1947, and M.S.M.E., University of Michigan, 1949*) senior project engineer, Research and Future Products Engineering Department, inventor in patent 2,846,854 for an ice cube maker.
- **James W. Jacobs**, (*B.S.M.E., University of Dayton, 1954*) section engineer, Non-Refrigerated Appliances Engineering Department, inventor in patent 2,847,681 for a self-rinsing sink; in patent 2,848,200 for a heat exchanger; in patent 2,850,884 for a refrigerating apparatus; and in patent 2,851,865 for a vehicle refrigerating apparatus.
- **Millard E. Fry**, (*B.S.M.E., University of Pittsburgh, 1931*) senior project engineer, Non-Refrigerated Appliances Engineering Department, and **Jesse L. Evans**, (*B.S.M.E., University of Dayton, 1943*) senior project engineer, Engineering Department, inventors in patent 2,851,029 for a domestic appliance.
- **George C. Pearce**, (*B.S.M.E., Stanford University, 1924*) section head, Non-Refrigerated Appliances Engineering Department, inventor in patent 2,851,571 for an electric heating unit.
- **Albert L. Henne**, (*Ph.D. in chemistry, University of Brussels, 1926*) consultant, and **Victor A. Williamitis**, (*B.Chem.E., University of Dayton, 1938*) senior experimental chemist, Materials and Process Engineering Department, inventors in patent 2,852,470 for a refrigeration composition.
- **George B. Long**, (*B.S.E.E., Purdue University, 1937*) supervisor, major product line, Research and Future Products Engineering Department, inventor in patent 2,853,248 for a domestic garbage disposal unit with impeller operable only above a predetermined speed range.

GMC Truck and Coach Division
Pontiac, Michigan

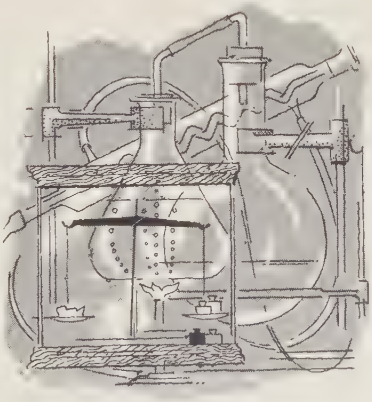
- **William T. Litherland**, project engineer, Electrical Engineering Department, inventor in patent 2,841,389 for a door apparatus and control.
- **Hans O. Schjolin**, (*B.S., Karlstad College, Sweden, 1920, and Polytechnical Institute, Mittweida, Germany, 1923*) new development engineer, Engineering Department, and Everett W. Allen, retired, inventors in patent 2,841,963 for a refrigerating apparatus.
- **Edwin T. Todd**, (*B.A.M.E., and B.A.Aero.E., Stanford University, 1924; University of California; College of the Pacific; and Davis Agricultural College*) amphibious truck engineer, Advance Design Department, inventor in patent 2,847,872 for an adjustable plural control device.
- **Adam S. Lamont**, general foreman, Experimental Machine Shop, and **Edwin T. Todd***, inventors in patent 2,849,047 for a pressure control system.
- **Hans O. Schjolin***, and **Donald K. Isbell**, senior engineer, Engineering Department, inventors in patent 2,849,087 for a wheel and brake assembly.
- **William P. Strong**, (*Toledo University*) staff engineer—coaches, Engineering Coach Department, inventor in patent 2,852,085 for an engine mounting means for motor vehicles.

GM Overseas Operations Division
New York, New York

- **Jakob A. Adloff**, (*engineering degree, Rheinische Ingenieurschule, Bingen, Germany, 1927*) head of Development Section, Engineering Department, Adam Opel A.G., Russelsheim/Main, Germany, inventor in patent 2,841,028 for a gear shift mechanism for motor vehicles.

Guide Lamp Division
Anderson, Indiana

- **Charles W. Miller**, (*Purdue University*) project engineer, Engineering Department, inventor in patent 2,840,758 for a light sensitive control system.
- **Edward L. Barcus**, senior designer, drafting, Engineering Department, inventor in patent 2,848,573 for a direction signal switch mechanism.



- **Eugene G. Matkins**, (*B.M.E., General Motors Institute, 1952*) project engineer, Engineering Laboratory, inventor in patent 2,848,650 for a light actuated control circuit.
- **Charles W. Miller***; **George W. Onksen**, (*Purdue University and B.I.E., General Motors Institute, 1956*) engineering head, Research and Development Department; and **Myrneth L. Woodward**, electronics engineer, Engineering Laboratory, inventors in patent 2,854,604 for a headlight dimmer system.

Inland Manufacturing Division
Dayton, Ohio

- **Max P. Baker**, (*A.B., Miami University, 1922*) project engineer, Engineering Department, inventor in patent 2,841,967 for a universal joint; in patent 2,847,837 for a fluid seal, and in patent 2,852,287 for a resiliently bonded pivot joint unit.
- **Arthur J. Frei**, senior project engineer, inventor in patent 2,846,855 for an ice block maker.

Moraine Products Division
Dayton, Ohio

- **Frederick W. Sampson**, (*M.E., Cornell University, 1924*) section engineer on special assignment, inventor in patent 2,845,810 for a steering wheel.
- **Frederick W. Sampson***, and Stanley R. Carson, deceased, inventors in patent 2,847,695 for a windshield wiper arm.

New Departure Division
Bristol, Connecticut

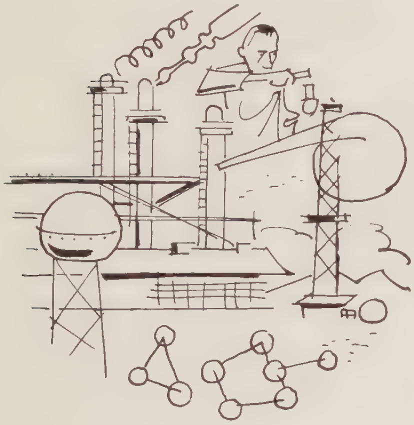
- **Leland D. Cobb**, (*E.E., Pratt Institute, 1928*) manager, Research and Development Laboratory, inventor in patent 2,850,792 for a method of applying a bearing seal.

GM Research Laboratories
Detroit, Michigan

- **Walter E. Sargeant**, (*B.S.E.E., University of Michigan, 1926*) senior research engineer, Physics Department, and Edward J. Martin, retired, inventors in patent 2,833,985 for a permeameter.
- **Joseph B. Bidwell**, (*B.S.M.E., Brown University, 1942*) head, Engineering Mechanics Department, and John H. Brema, no longer with GM, inventors in patent 2,841,008 for a surface smoothness measuring means.
- **Floyd A. Wyczalek**, (*B.S.M.E., Worcester Polytechnic Institute, 1946*) now supervisor, Power Development Group, GM

Engineering Staff, inventor in patent 2,843,103 for a combustion chamber.

- **Alfred L. Boegehold,** (*M.E., Cornell University, 1915*) consultant, inventor in patent 2,843,374 for a shell hardened torsion bar and process of making same.
- **Arthur A. Vuylsteke,** (*M.S. in physics, University of Michigan, 1951*) senior physicist, Physics Department, inventor in patent 2,845,257 for a carburetor.
- **Carl L. Goodzeit,** (*B.S.M.E., Rutgers University, 1950, and M.S.E., Brown University, 1955*) senior research engineer, Mechanical Development Department, inventor in patent 2,845,918 for bearing surfaces.
- **LaVerne R. Voss,** (*B.S.M.E., Bradley University, 1951*) research engineer, Physics Department, and **Arthur A. Vuylsteke***, inventors in patent 2,846,203 for a carburetor.



- **Raymond A. Gallant,** (*B.M.E., Rensselaer Polytechnic Institute, 1950, and M.S. in engineering mechanics, University of Michigan, 1954*) now engineering laboratory supervisor, Chevrolet Motor Division, inventor in patent 2,847,984 for a hydraulic engine starting device.
- **Archie D. McDuffie,** (*General Motors Institute, 1934*) now with Buick Motor Division, inventor in patent 2,848,287 for a piston head construction.
- **Joseph E. Hunter, Jr.,** (*B.S. Met. E., Michigan State University, 1950*) metallurgical engineer, Metallurgical Engineering Department, and **Norman W. Schubring,** research engineer, Physics and Instrumentation Department, inventors in patent 2,848,891 for an apparatus for ultrasonic testing.
- **Gregory Flynn, Jr.,** (*General Motors Institute, 1941*) head, Mechanical Development Department, inventor in patent 2,848,984 for an oil cooling arrangement for free piston gasifier.
- **William A. Turunen,** (*B.S.M.E., Michigan College of Mining and Technology, 1939, and M.S. degree, Columbia University, 1946*) head, Gas Turbine Department, and Patrick O'Connell, deceased, inventors in patent 2,849,210 for a turbine blade cooling system.
- **Robert F. Thomson,** (*B.S.M.E., 1937; M.S.M.E., 1940; and Ph.D., 1941, University of Michigan*) head, Metallurgical Engineering Department, inventor in patent 2,849,789 for a sintered powdered copper base metal and bearing formed thereof.
- **Joseph L. Greene,** (*B.A. in chemistry, Wayne State University, 1956*) research chemist, Metallurgical Engineering Department, and **James C. Holzwarth,** (*B.S., 1945, and M.S., 1948, Purdue University*) supervisor, Metallurgical Engineering Department, inventors in patent 2,850,441 for a chemical displacement process of plating cadmium on aluminum.
- **James D. Fleming,** (*B.S.M.E., Texas Technological College, 1947, and M.S., 1948, and Ph.D., 1950, University of Wisconsin*) senior research engineer, Mechanical Development Department and **Henry F. Reinhart,** (*Detroit College of Applied Science*) designer, Mechanical Development Department, inventors in patent 2,851,019 for a combustion chamber for internal combustion engine.
- **Jerar Andon,** (*B.M.E., General Motors Institute, 1951*) now senior project engineer, Power Development Group, GM Engineering Staff; **Boris J. Mitchell,** (*B.S.M.E., Detroit Institute of Technology, 1940*) now assistant engineer in charge, Engine Development Section, Power Development Group, GM Engineering Staff; and **Ralph E. Schwind,** (*B.S.M.E., Purdue University, 1950, and S.M.M.E., Massachusetts Institute of Technology, 1951*) product engineer, Product Engineering Department, Fabricast Division, inventors in patent 2,851,022 for a poppet valve operating mechanism.
- **Alfred W. Schlucter,** (*B.S.Chem.E., 1919; M.S.Chem.E., 1921; and Ph.D., 1926, University of Michigan*) research engineer, Mechanical Development Department, inventor in patent 2,852,365 for an aluminum base bearing.
- **Richard C. Drutowski,** (*B.S.E.E.; B.S. in mathematics; and M.S. in physics, University of Michigan*) supervisor of friction research, Mechanical Development Department, inventor in patent 2,854,299 for an antifriction bearing.

Oldsmobile Division

Lansing, Michigan

- **Lloyd T. Gill,** (*General Motors Institute, 1939*) design group leader—motor group, Product Engineering Department, inventor in patent 2,845,911 for an induction system.
- **Ralph C. Bird, Jr.,** (*B.S.M.E., Michigan State University, 1933*) senior project engineer—engine group, Product Engineering Department, inventor in patent 2,845,912 for an induction system.
- **James H. Diener,** (*B.S.M.E., Purdue University, 1938*) senior project engineer—chassis group, Product Engineering Department, and **George T. Jones,** (*University of Pittsburgh, 1934*) body engineer—body group, Product Engineering Department, inventors in patent 2,851,118 for a bumper exhaust.
- **Robert Seyfarth,** (*B.S.M.E., Princeton University, 1936*) senior engineer—engine group, Product Engineering Department, inventor in patent 2,851,894 for a variable diameter pulley.

Pontiac Motor Division

Pontiac, Michigan

- **Vinton P. Birch,** (*General Motors Institute, 1943, and University of Washington, and Detroit Institute of Technology*) senior project engineer, Engineering Department, inventor in patent 2,841,371 for a throttle actuating mechanism.
- **Clayton B. Leach,** (*A.B. in mathematics and chemistry, Park College, 1934, and General Motors Institute*) chassis engineer, Engineering Department, inventor in patent 2,845,051 for a cooling system for engines; in patent 2,847,820 for a crossover exhaust system for V-8 engines; in patent 2,849,993 for a camshaft gallery structure for engines; and in patent 2,853,063 for an engine with reversible heads, couplings, and gaskets.
- **Raymond W. Van Dinen,** assistant master mechanic, Master Mechanics Department, inventor in patent 2,852,265 for a work holder and centering means.

These patent listings are informative only and are not intended to define the coverage which is determined by the claims of each one.

GM Process Development Staff
Detroit, Michigan

- **George E. Groener,** (*B.S.M.E., Wayne State University, 1948*) senior project engineer, Engineering Department, and George R. Squibb, no longer with GM, inventors in patent 2,845,525 for welding equipment.

- **Clarence G. Chambers,** (*General Motors Institute, 1932, and B.S.M.E., Wayne State University, 1937*) supervisor, Laboratories, and **Robert A. Spaulding,** (*B.S.Chem.E., University of Illinois, 1945, and M.S., Purdue University, 1949*) senior plating engineer, Engineering Department, inventors in patent 2,846,379 for plating equipment and method of plating piston rings.

- **George E. Groener*,** inventor in patent 2,852,849 for a pneumatic gauging device.

Rochester Products Division
Rochester, New York

- **Joseph M. McDonnell,** (*Newark College of Engineering*) senior engineer, and **Galer N. Wright,** (*University of Rochester*) sales representative, Product Sales and Service Department, inventors in patent 2,846,241 for a pipe end to pipe side joint.

- **Howard H. Dietrich,** (*B.S.E.E., Purdue University, 1926, and Yale University*) patents, new devices, and project analysis engineer, Engineering Department, inventor in patent 2,847,983 for a fuel injection system.

- **Arthur C. Bennett,** (*B.S.M.E., University of Rochester, 1950*) senior project engineer, Product Engineering and Development Department, inventor in patent 2,848,201 for a carburetor.

- **Lawrence C. Dermond,** (*Purdue University and Tri-State College*) staff engineer, inventor in patent 2,848,986 for a fuel injection system.

- **Clarence H. Jorgensen,** (*University of Wisconsin and University of Michigan*) chief research engineer, Research and New Product Development Department; **John M. Barr,** (*B.S.M.E., Rose Polytechnic Institute, 1925*) senior research engineer, Advance Design Department; **Howard H. Dietrich*;** **Willard T. Nickel,** now with AC Spark Plug Division; and **Mark R. Rowe,** (*B.M.E., New York University, 1940*) head, Engine Control Department, inventors in patent 2,849,862 for an engine controller.

- **Elmer Olson,** (*Lewis Institute*) inventor in patent 2,851,259 for an idle vent valve.

- **Clarence H. Jorgensen*; Willard T. Nickel*; John M. Barr*; and Howard H. Dietrich*,** inventors in patent 2,852,913 for an automatic mechanism for controlling fuel flow to a jet engine.

Saginaw Steering Gear Division
Saginaw, Michigan

- **Philip B. Zeigler,** (*B.S.M.E., Purdue University, 1941*) chief engineer, Product Engineering Department; C. W. Lincoln, retired; and Henry D. Spiekerman, no longer with GM, inventors in patent 2,844,970 for a transmission control external tube.

- **Earl W. Glover,** designer, Product Engineering Department, inventor in patent 2,845,782 for a ball bearing spline.

- **Robert P. Rohde,** (*B.S.M.E., University of Michigan, 1950*) senior project engineer, Product Engineering Department, and **Paul V. Wysong, Jr.,** (*University of Kansas*) sales supervisor, Actuators, inventors in patent 2,848,009 for an unloading valve.

- **David M. Gurney,** (*B.S.M.E., and B.S.A.E., Tri-State College, 1948*) project engineer, Product Engineering Department, inventor in patent 2,850,715 for a contact and bearing assembly.

GM Styling Staff
Detroit, Michigan

- **Marcel O. DeVos,** in charge of interior soft trim and fabric design, Interior Design Studio, and Letcher B. Hunt, Jr., no longer with GM, inventors in patent 2,841,212 for a folding extensible arm rest.

- **Frank W. Loeffler,** project engineer, Oldsmobile Studio, inventor in patent 2,841,232 for an exhaust means extending through accessible enclosures.

- **Kenneth A. Pickering,** (*B.S.M.E., Pennsylvania State University, 1949*) staff assistant to the director of Styling, inventor in patent 2,845,299 for a vehicle top compartment cover mechanism.

- **Ned F. Nickles,** chief designer, Advanced Design Studio No. 1, inventor in patent 2,846,261 for a gas tank filter door.

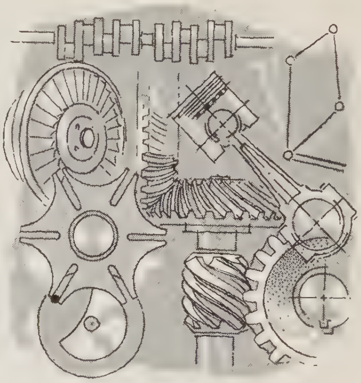
- **Delbert C. Probst,** (*Milliken University, 1922*) senior design engineer, Exterior Engineering Department, inventor in patents 2,846,265 and 2,854,272 for a ventilation window booster and a door latch and striker, respectively.

- **Robert F. Smith,** (*General Motors Institute, 1930*) assistant in charge of engineering, Product and Exhibit Design Studio, inventor in patent 2,852,329 for an adjustable refrigerator shelf.

- **Kenneth R. Betts,** (*Tri-State College, 1925*) project engineer, Chevrolet Truck Studio, inventor in patent 2,853,933 for a heating, ventilating and defrosting system for vehicles.

Ternstedt Division
Detroit, Michigan

- **LaVerne B. Ragsdale,** (*University of Detroit, Franklin College, and B.S.M.E., Lawrence Institute of Technology, 1939*) staff engineer, Product Development Department, inventor in patent 2,840,139 for a single track seat adjuster.



- **Thomas E. Lohr,** (*Tri-State College*) senior design engineer, New Product Development Section, Product Engineering Department, inventor in patent 2,844,969 for a mechanical movement device.

- **Bewley D. Priestman,** (*B.A. in engineering science, 1938, and M.A.M.E., 1937, University of Cambridge, England*) engineering group supervisor, Product Engineering and Development Department, inventor in patents 2,845,291 and 2,852,296 for a retaining clip and assembly and a rotary gear bolt door latch, respectively.

- **Samuel F. Loria,** (*B.S.M.E., Detroit Institute of Technology, 1939*) chief draftsman, Product Development Department, inventor in patent 2,848,736 for a hinge and hold open.

- **Russell G. Corbin,** (*B.S.M.E., University of Michigan, 1950*) design group leader, Product Engineering and Development Department, inventor in patent 2,849,251 for a door latch with slidable actuator.

Product History and Related Patents Dramatized in Exhibit

PRECISION ball bearings of many types were featured in a recent display developed by New Departure Division (Fig. 1). The display, set up in the U.S. Department of Commerce Building, Washington, D.C., was part of a public exhibit built around the theme, "Science, Industry, Invention, and the U.S. Patent Office." Another GM Division, Saginaw Steering Gear*, previously participated in the continuing series of exhibits designed to dramatize mechanical progress as developed through assistance from the U.S. patent system.

In addition to displaying a wide assortment of ball bearings manufactured by New Departure (GM's oldest operating unit in the United States), the exhibit included many other items. Among the additional items shown were: New Departure's first product—a push-button doorbell, first introduced in 1888; bicycle accessories, which were among early New Departure products; and equipment developed by the bearing firm for the purpose of testing and gaging bearings. Also on display were more than 25 copies of original patents granted to New Departure over the years. The patents pertained to ball bearings and equipment used in their manufacture. Most of the 70,000 exhibit viewers also saw New Departure's unique ball bouncing machine, which occupied a place in the exhibit.

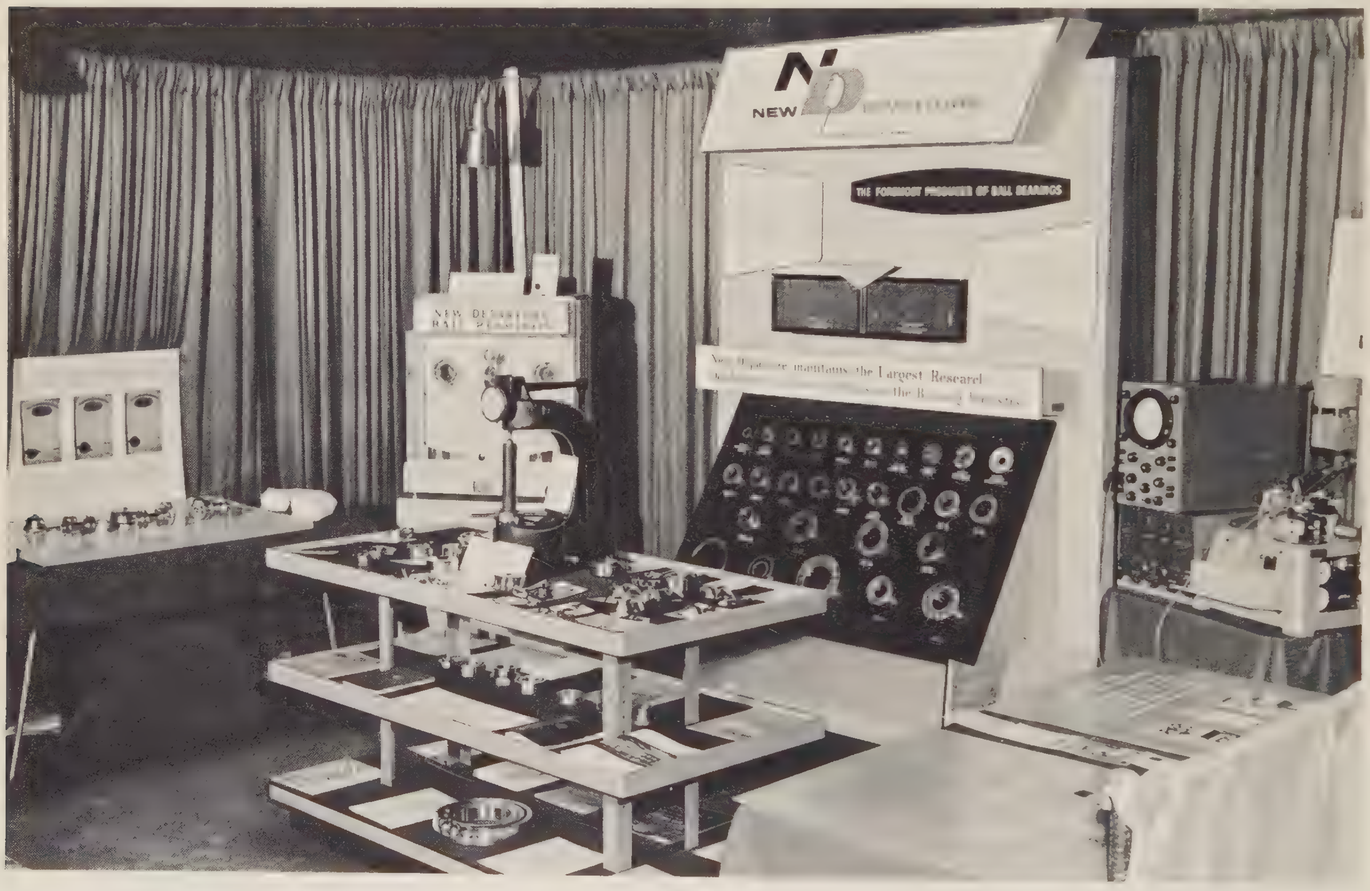

NEW
THE FOREMOST PRODUCER OF BALL BEARINGS
NEW DEPARTURE BALL BEARINGS
maintains the Largest Research

Fig. 1—A display of ball bearings, testing and gaging equipment, along with many other items of New Departure Division was viewed by some 70,000 persons recently during a U. S. Department of Commerce public exhibit. Purpose of the exhibit was to dramatize the progress of American industry made possible to a large extent by our country's patent system.

Preceding the informal official opening of the industrial exhibits was an industry-commerce conference. Among those who spoke at the conference was Seth H. Stoner, general manager, New Departure Division. In his remarks Mr. Stoner advocated having patent examiners, particularly those young in the service, personally visit industries to obtain firsthand information relative to devices on which patents are being sought.

As a result of the New Departure display, and upon invitation from Robert C. Watson, U.S. Commissioner of Patents, the Division conducted a symposium at the U.S. Patent Office in Washington on the subject of ball bearing manufacture. Some 40 patent examiners attended the one day session that followed the exhibit opening.

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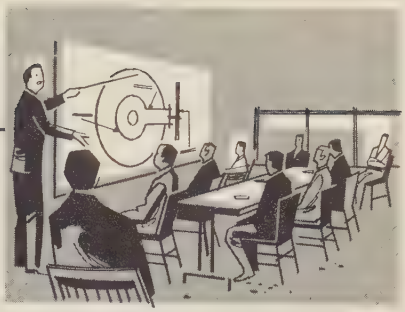
*"Progress Under Patent System Told in Public Exhibit," GENERAL MOTORS ENGINEERING JOURNAL, Vol. 5, No. 1 (January-February-March 1958), p. 47.

Technical Presentations by GM Engineers and Scientists



The technical presentation is another way in which information about current engineering and scientific developments in General Motors can be made available to the public. A listing of speaking appearances by General Motors engineers and scientists, such as that given below, usually includes the presentation of papers before professional societies, lecturing to college engineering classes or student societies, and speaking to civic or governmental organizations. Educators who wish assistance in obtaining the services of GM engineers and scientists to speak to student groups may write to the Educational Relations Section, Public Relations Staff, General Motors Technical Center, P. O. Box 177, North End Station, Detroit 2, Michigan.

GM personnel who have made recent technical presentations are as follows:

Automotive Engineering

Francis J. Kalvelage, senior project engineer, Physical Testing Laboratory, Body Engineering Activities, Fisher Body Division, before the northern Ohio chapter of the Society for Experimental Stress Analysis, Cleveland; title: Structural Testing of Automobile Bodies.

Vaughan H. Hardy, chief engineer, Delco Appliance Division, before the Niagara Frontier section of the American Industrial Engineers, Buffalo, August 9; title: Automated Automobiles.

Kenneth A. Stonex, assistant director, GM Proving Grounds, before the First International Skid Prevention Conference, Charlottesville, Virginia, September 9; title: Elements of Skidding, and before the 7th Governor's Safety Conference, Topeka, Kansas, October 9; title: Safety Aspects of Vehicle-Road Relationships.

W. H. Jackson, supervising engineer, air conditioning section, Engineering Department, Harrison Radiator Division, before the American Refrigeration Institute, Tubular Products Section, Port Huron, Michigan, September 10; title: General Motors Automotive Air Conditioning.

R. C. Waters, rubber and plastics engineer, GMC Truck and Coach Division, before the Society of Plastics Engineers, St. Clair, Michigan, September 12; title: More Plastics in Automobiles—How?

John M. Beltz, assistant chief engineer, Product Engineering Department, Oldsmobile Division, before the Kiwanis Club, Okemos, Michigan, October 1; title: Automotive Styling.

R. J. Gorskey, staff engineer, transmissions, Buick Motor Division, before the southern Michigan section of the Society for Experimental Stress Analysis, Flint, October 7; title: Buick's Twin Turbine Transmission Reverse Band Load Study.

William S. Shade, staff engineer, Engineering Department, Diesel Equipment Division, before the Milwaukee chapter of the Society of Automotive Testers, October 13; title: Hydraulic Valve Lifters.

Zora Arkus-Duntov, assistant staff engineer, Special Design and Development Department, Chevrolet Motor Division, before the Madison Avenue Sports Car Driving and Chowder Society, New York City, October 14; title: Automobile Performance.

C. V. Crockett, chief engineer, GMC Truck and Coach Division, before ordnance officials, Pentagon Building, Washington D.C., October 21-22; title: The GMC Engine Family.

L. A. Zwicker, chief engineer, Harrison Radiator Division, before the Society of Automotive Engineers national transportation meeting, Baltimore, Maryland, October 22; title: Concepts in Truck Cooling—Heat Exchangers.

Harry D. Wright, Jr., car test supervisor, Car Test Engineering Department, Delco Products Division, before the Delco Co-Op Club, Dayton, October 23; title: GM Air Suspension.

Hans O. Schjolin, new development engineer, Engineering Department, GMC Truck and Coach Division, before the National Association of Motor Bus Operators, Boca Raton, Florida, October 23; title: Hydrashift Transmission for Intercity Coaches.

John A. Robinson, staff engineer, chassis design, Buick Motor Division, before students of Flint, Michigan, Central High School, October 29; title: Automotive Design.

Charles J. Brady, assistant manager, GM Desert Proving Ground, Mesa, Arizona, before the S.A.E. National Fuels and Lubricants Meeting, Tulsa, Oklahoma, November 6; title: Measuring the Hot Fuel Handling Characteristics of Automobiles.

Before various S.A.E. section meetings: **Donald McPherson,** assistant staff engineer, Passenger Car Engine Design Department, Chevrolet Motor Division, before the Muskegon, Michigan, section, October 7; title: Engineering the "W" Engine—Chevrolet's 348 Cubic Inch V-8; **Edwin E. Nelson,** project engineer, Power Development Group, GM Engineering Staff, before the Philadelphia section, October 8; title: A New Look at High Compression Engines; **Edwin E. Nelson,** and **Darl F. Caris,** engineer in charge, Power Development Group, GM Engineering Staff, before the New York Metropolitan section, October 16; title: A New Look at High Compression Engines; **Harry S. Ford, Jr.,** project engineer in charge of combustion group, Detroit Diesel Engine Division, before the Baltimore, Maryland, section, October 22; title: Multifuel Experience With GM Model 71 Engines; **Virgin C. Reddy,** development engineer, Detroit Diesel Engine Division, before the Baltimore, Maryland, section, October 23; comments on an S.A.E. paper entitled "Priming Aids for Cold Starting Diesel Engines;" **Louis C. Lundstrom,** director, GM Proving Grounds, before the Mid-Michigan section, Saginaw, October 27; title: Safety Aspects of Vehicle-Road Relationships; and **Peter Ashurkoff,** project engineer, Power Development Group, GM Engineering Staff, before the Rochester, New York, section, November 10; comments on an S.A.E. paper entitled "A Method of Charge Stratification for

Four Stroke Cycle Spark Ignition Engines."

Bearings and Lubrication

Fred G. Rounds, senior research engineer, Fuels and Lubricants Department, GM Research Laboratories, before the American Chemical Society, Chicago, September 9; title: Influence of Lubricant Composition on Friction of Steel on Steel.

Roy L. Bowers, staff engineer, Automotive Engineering Department, AC Spark Plug Division, before the Flint chapter of the Michigan Trucking Association, September 9; title: Filtration of Automobile Crankcase Oils.

John Dickson, staff engineer—forward design, Detroit Diesel Engine Division, before the Dallas, Texas, chapter of the American Society of Lubrication Engineers, September 25; title: Lubrication.

W. K. Simpson, fuel and lubricant engineer, Engineering Department, Electro-Motive Division, before the American Society of Lubrication Engineers, Montreal, Quebec, October 1; title: Lubrication of Diesel Electric Locomotives.

Engineering personnel of Hyatt Bearings Division, Product Engineering Department, who appeared before engineers of the General Electric Bearing Board, Evendale, Ohio, October 1: **Carl W. Kalchthaler,** chief engineer, title: Precision Bearing Development Trends; **John F. Moult,** assistant chief engineer—aircraft, title: Precision Bearing Installation and Design Concepts; and **Mark E. Otterbein,** manager—research and development, title: Precision Bearing Development and Testing Program.

P. A. Bennett, supervisor, Fuels and Lubricants Department, GM Research Laboratories, before the A.S.M.E.-A.S.L.E. Lubrication Conference, Los Angeles, October 13; title: A Surface Effect Associated with the use of Zinc Dialky-Idithiophosphate-Treated Oils, and before the Tulsa, Oklahoma, S.A.E. Fuels and Lubricants Meeting, November 6; title: A Look at the Effect of Lubricant Additives on Surfaces.

Heinz Hanau, supervisor, aircraft projects, Aircraft Section, Product Engineering Department, New Departure Division, before the A.S.M.E.-A.S.L.E. Joint Lubrication Meeting, Los Angeles, October 14; comments on a paper presented before the meeting entitled "An Accessory Manufacturer's Approach to Bearing and Seal Development."

T. W. Bakewell, supervisor, machine tool projects, Application Section, Product Engineering Department, New Departure Division, before the Detroit chapter of the American Society of Tool Engineers, November 6; title: Ball Bearings for Machine Tools.

Electrical Engineering

R. H. Bertsche, electrical engineer, Engineering Department, GMC Truck and Coach Division: U.S. delegate to I.S.O. for Standardization of Automobile Lighting, Konstanz, Germany, September 15-20; U.S. delegate to Engineering Committee—Bureau of Permanent International Des Constructural D'Automobiles, Paris, France, September 30-October 3; before the American Transit Association, New Orleans, October 15; title: Latest Developments in Generator and Voltage Control Equipment; and before the Canadian Transit Association, Niagara Falls, Ontario, November 11; title: Recent Developments in Generators and Regulators.

L. V. Ostrander, research engineer, Electronics Instrumentation Department, GM Research Laboratories, before the Philadelphia chapter of the Instrument Society of America, September 18; title: Desired Improvements in Instrumentation Used in the Automobile Industry.

Victor Muth, test engineer, AC Spark Plug Division, before the American Institute of Electrical Engineers, Milwaukee, October 3; title: Recording Instrumentation at AC.

F. W. Whitford, senior project engineer, Mechanical Engineering Department, Delco Radio Division, before the Institute of Printed Circuits, Inc., Chicago, October 14; title: Printed Wiring Board Design Parameters for High Volume Radio Production.

Robert R. Bockemuehl, senior research engineer, Physics Department, GM Research Laboratories, before the National Electronics Conference, Chicago, October 15; title: Gated Amplitude Ratio Indicator.

Howard W. McKenna, research engineer, Electronics Instrumentation Department, GM Research Laboratories, before the University of Detroit chapter of the I.S.A., October 16; title: An Introduction to DC Analog Computers.

L. W. Tobin, Jr., chief engineer, Automotive Engineering Department, AC Spark Plug Division, before the Flint Rotary Club, October 24; title: Atoms, Electronics, and You.

A. E. Manes, field service engineer, Service Department, Delco Radio Division, before the Brooklyn, New York, Auto Radio Repair Association, November 12; title: Fundamentals of Transistors and Auto-Portable Radios.

Foundry

W. C. Cheek, superintendent, Process Engineering Department, Central Foundry Division, before the American Foundrymen's Society, Chicago, August 18; title: Production Pattern Equipment.

Norman W. Schubring, senior research engineer, and **James E. Stevens,** research engineer, Physics Department, GM Research Laboratories, before the Industrial Electronics Symposium, I.R.E., Detroit, September 25; title: Multi-Channel Swept Sonic Tester for Casting Quality Control.

Darl F. Caris, engineer in charge, Power Development Group, GM Engineering Staff, before the Gray Iron Founders' Society, Inc., Washington, D.C., October 9; title: The Implications of the Aluminum Automobile Engine.

Conrad F. Orloff, staff engineer, Production Engineering Department, Chevrolet Motor Division, before the A.F.S., Ann Arbor, Michigan, October 16; title: Casting and the Automobile Industry.

O. V. Saunders, supervisor of major products, Refrigerated Appliances Engineering Department, Frigidaire Division, before the Society of Die Casting Engineers, Holland, Michigan, November 11; title: Application of Die Castings on Refrigerators.

David C. Salatin, staff engineer, Metal Casting Laboratory, Process Development Section, Process Development Staff, before the Flint chapter of the A.S.T.E., November 13; title: Evaluation of Vacuum Die Casting.

Guided Missiles

Engineering personnel of AC Spark Plug Division's Milwaukee, Wisconsin, facility who made recent presentations on guided missiles and inertial guidance systems are as follows:

Kenneth Schlager, supervisor, system analysis group, Regulus missile, before

M.S.O.E. students, Milwaukee, August 12; and before the Central Y.M.C.A. Tri Men's Club, Milwaukee, August 15; title: Missile Guidance Systems.

Anthony J. Italiano, assistant technical director, Mace missile, before the Wauwatosa, Wisconsin, Rotary Club, August 27; before the Pewaukee, Wisconsin, High School P.T.A., October 1; title: Missile Guidance; before the Elm Grove Kiwanis Club, September 10; title: Missiles and Inertial Guidance; and before the Waukesha, Wisconsin, chapter of Professional Engineers, September 24; title: History of Missile Guidance.

William French, project business manager, before the Milwaukee Kiwanis Club, September 29; title: AC Spark Plug in the Missile Program.

Jack Schmidt, engine control engineer, before the Jaycee Bavarian Club, Milwaukee, September 16; title: Inertial Guidance and Missiles; before group teachers of the Boys Technical High School, Milwaukee, October 8; title: Missile Guidance; before the Nicolet High School Science Club, Milwaukee, October 8; title: The MITAC Gyroscope; and before the Cornell Paper Company 20-Year Club, Milwaukee, October 11; title: How to Meet the Man in the Moon.

Karl Krull, technical writer, before the St. Paul's Lutheran Brotherhood, Milwaukee, October 14; title: Missiles.

Sidney Hatch, administrative assistant to project director, before the Northwest Mutual Life Insurance Company, Milwaukee, October 14; title: Missile Guidance; and before the Eastside Businessmen's Association of Milwaukee, October 30; title: Missiles.

William R. Goris, assistant technical director, before high school students of Burlington, Wisconsin, October 16; title: Scientific Applications on Ballistic Missiles.

Charles Smitkamp, administrative engineer, before fifth grade students of Washington High, Milwaukee, October 22; title: Missiles and Guidance.

Donald L. Carpentier, Regulus missile project engineer, before the Westside Optimist Club, Milwaukee, October 16; title: The Missile—A Challenge to Industry.

Manufacturing

Edward R. Clark, supervisor, quality control engineering, Inspection Department, Detroit Transmission Division, before University of Michigan students enrolled in a special quality control course, Ann Arbor, August 26; title: Application of Quality Control Techniques.

Harry D. Hall, director, Process Development Section, GM Process Development Staff, before the Windsor, Ontario, chapter of the A.S.T.E., September 15; title: Manufacturing Process Development as a Staff Function.

A. A. Klautsch, senior instructional specialist, Psychology Department, General Motors Institute, before the Newark, New Jersey, chapter of the Materials Handling Society, September 17; title: Obtaining Cooperation.

Joseph O. McGinnis, senior instructional specialist, Industrial Engineering Department, General Motors Institute, before the 4th Annual Joint Military-Industry Packaging Conference, Navy Office, Washington, D. C., October 2; title: Material Handling and Packaging Resident Technical Training Program.

Stanley B. Sherwood, quality control engineer, Production Engineering Section, GM Process Development Staff, before the Youngstown, Ohio, section of the American Society for Quality Control, October 2; title: Machine Capability—A Common Language Tool.

Charles A. Nichols, technical assistant to the vice president, GM Process Development Staff, before the Rochester, New York, chapter of the A.S.T.E., October 6; title: Tool Engineering.

David Milne, supervisor, materials and processes, Production Engineering Section, GM Process Development Staff, before the Annual Meeting of the Federation of Sewage and Industrial Wastes Association, Detroit, October 8; title: Organization for Liquid Waste Control in General Motors, and before the Indiana Sewage and Industrial Waste Conference, Indianapolis, November 6; title: Industrial Waste Control Activities in General Motors Plants in Indiana.

Metallurgy

Robert F. Thomson, head, Metallurgical Engineering Department, GM Research Laboratories, before the Symposium on Internal Stress and Fatigue in Metals, Detroit, September 4; title: Engineering Interest in Internal Stress; before the Gray Iron Founders' Society, Washington, D. C., October 9; title: The Implications of the Aluminum Automobile Engine; and before the American Society for Metals, Detroit, October 14; title: Are Metallurgists Prepared for 19XX?

Robert C. Frank, senior research physicist, Physics Department, GM Research Laboratories, before the Symposium on Internal Stress and Fatigue in Metals, Detroit, September 5; title: Time Dependent Effects of Hydrogen in Steel.

Robert B. Allured, senior project engineer, Electronics Department, GM Process Development Staff, before the Detroit chapter of the I.R.E., September 25; title: Automatic Hardness Tester.

George H. Robinson, supervisor, Metallurgical Engineering Department, GM Research Laboratories, and **Harry J. Gilliland,** senior metallurgical engineer, Process Development Section, GM Process Development Staff, before the A.S.M., Cleveland, Ohio, October 28; title: Evaluation of Quenching Media.

Seward E. Beacom, senior research chemist, and **Bernard J. Riley,** research chemist, Electrochemistry Department, GM Research Laboratories, before the Electrochemical Society, Ottawa, Canada, September 28; title: A Radioisotopic Study of Leveling in Bright Nickel Electroplating Baths.

Miscellaneous Subjects

Albert J. Kubany, senior staff specialist, Personnel Evaluation Services Department, General Motors Institute, before the American Psychology Association, Washington, D. C., September 2; title: Observation Methodology and Supervisory Behavior.

James White, engineering administration service supervisor, AC Spark Plug Division, before a management seminar at Marquette University, Milwaukee, September 16; title: Systems for Management.

Henry S. Smith, administrative engineer Product Engineering Department, Saginaw Steering Gear Division, before the drafting teachers section of the Michigan Education Association, Cadillac, October 2; title: Drafting in Industry.

William K. Steinhagen, assistant engineer in charge, Power Development Group, GM Engineering Staff, before the Richmond, Virginia, chapter of the American Society of Refrigeration Engineers, October 6; title: Design of an Axial Refrigeration Compressor.

Robert Hard, project engineer, AC Spark Plug Division, before the Flint, Michigan, Technical High School World Religions Club, October 8; title: Religion Among Primitive Societies.

Walter E. Mitchell, general administrator, Fisher Body Paint Standards Activity, before the Federation of Paint and Varnishes Production Clubs Convention, Cleveland, Ohio, October 8; title: Water Emulsion Paints.

J. M. Farrell, project engineer, Physics Department, GM Research Laboratories, before the Watchmakers Association of New Jersey, October 15; title: Electrical Timepieces.

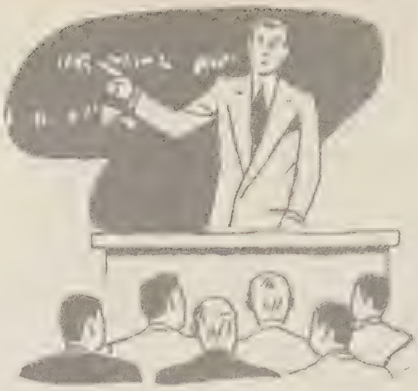
Gerald H. Zimmer, general supervisor, Package Engineering Department, Delco Products Division, before the Service Parts Packaging Committee, Chicago, October 16; title: Savings Realized by Sub-Contracting a Packaging Requirement.

Alfred McCutcheon, supervisor, methods suggestions, AC Spark Plug Division, before the Society for Advancement of Management, Milwaukee, October 23; title: Suggestion Programs.

Gordon S. MacFarland, chief draftsman, AC Spark Plug Division, before the Engineering Institute, University of Wisconsin Extension, Milwaukee, October 24; title: Design Standards—Mechanical and Electrical.

Dr. R. W. Smith, supervisor, metallurgy and physics, Research Laboratory, AC Spark Plug Division, before students of the Flint Junior College, October 29; title: Frontiers of Science.

Wallace E. Wilson, general manager, Rochester Products Division, before the Rochester, New York, Industrial Management Council — Training Director Group, November 10; title: A General Manager Looks at Training.



Before the engineering faculty of Kansas State College, November 11; **Harry Hawkins**, director of sales and engineering, Saginaw Steering Gear Division, title: How We Market and Service Our Products, and **Philip B. Zeigler**, chief engineer, Saginaw Steering Gear Division, title: How We Engineer Our Products.

H. O. Patterson, senior instructor, Psychology Department, General Motors Institute, before personnel and training officers of industrial and business concerns in the Milwaukee area, November 15; title: Reading Improvement Programs in Industry.

Edwin G. Bowman, general supervisor, Program Development Department, General Motors Institute, before the American Society of Training Directors, Detroit, November 17; title: Engineering Approach to Program Development.

Research

Carl E. Bleil, **Donald D. Snyder** and **Y. T. Sihvonen**, senior research physicists, Physics Department, GM Research Laboratories, before the International Conference on Semiconductors, Rochester, New York, August 18; title: Bombardment of CdS Crystals with 30 to 60 kev Electrons.

Harold W. Milnes, senior research scientist, Basic Science Department, GM Research Laboratories, and R. B. Potts, not with GM, before the American Mathematical Society, Cambridge, Massachusetts, August 29; title: Stability Criteria for the Numerical Solution of Partial Differential Equations by Boundary Contraction.

Robert V. Coleman, senior research physicist, Physics Department, GM Research Laboratories, before the International Crystal Growth Conference, Cooperstown, New York, August 28; title: Observations of Dislocations in Iron Whiskers, and before the Symposium on Internal Stress and Fatigue in Metals, Detroit, September 4; title: Deformation Phenomena in Single-Crystal Iron Whiskers.

Donald P. Koistinen, and **Richard E. Marburger**, senior research physicists, Physics Department, GM Research Laboratories, before the Symposium on Internal Stress and Fatigue in Metals, Detroit, September 4; titles: Internal Stresses Induced by Phase Transformations, and X-Ray Measurement of Internal Stresses.

Personnel of the GM Research Laboratories who made presentations at the Conference on Peaceful Uses of Atomic Energy, Geneva, Switzerland, September 1-13, were as follows: **Donald H. Loughridge**, head, Nuclear Power Engineering Department, title: The Design of a Gas Cooled Reactor, Closed Cycle Gas Turbine Propulsion System for Merchant Ships; **Farno L. Green**, senior research physicist, Physics Department, title: New Low Energy Photon Sources for Industrial Utilization; **Francis E. Jablonski**, senior nuclear physicist, Nuclear Power Engineering Department, and R. S. Carter, not with GM, title: A Study of Research Reactors for Reducing the Fast Neutron and Gamma Ray Background for Beam Experiments; and **Alexander Somerville**, supervisor, **John P. Danforth**, senior research engineer, **Farno L. Green**, senior research physicist, and **William J. Mayer**, senior research chemist, Physics Department, title: The Operation of the General Motors Radioisotope Training and Industrial Applications Program.

David L. Fry, supervisor, Physics Department, GM Research Laboratories, before the Symposium on Applied Spectroscopy, Ottawa, Canada, September 15; title: ASTM Committee E-2 on Emission Spectroscopy.

Carl E. Bleil, and **Donald D. Snyder**, senior research physicists, Physics Department, GM Research Laboratories, before the American Optical Society, Detroit, October 10; title: Luminescence of CdS Crystals at Room Temperature Under Intense Irradiation.

David E. Martin, senior research engineer, Special Problems Department, GM Research Laboratories, before students of the Mechanics Department, Michigan State University, East Lansing, October 16; title: Mechanics of Fatigue Failure.

Hal H. Rice, senior ceramic engineer, Metallurgical Engineering Department, GM Research Laboratories, before the Refractory in Organic Coating Symposium, Dayton, Ohio, October 28; title: Some Aspects of Bonding Ceramics and Cermets to Refractory Metals.

Harold A. Kahler, liaison engineer, Electrochemistry Department, GM Research Laboratories, before the National Association of Corrosion Engineers, Boston, November 12; title: Automotive Trim—Accelerated Testing and Service Performance.

Alexander Somerville, supervisor, Physics Department, GM Research Laboratories, before the 389th Meeting of the National Industrial Conference Board, Cleveland, November 13; title: The Industrial Use of Radioisotopes as Reported at the Geneva Conference.

Technical Careers and Vocational Guidance

Emmet C. Moynihan, resident engineer, Production Engineering Department, Tonawanda, New York, plant, Chevrolet Motor Division, before seniors of Hutchinson Central High School, Buffalo, October 21; title: Opportunities for Young Men in Automotive Engineering.

John A. Cravens, special representative, Sales Development Department, Euclid Division, before the Case Institute of Technology student chapter of the American Society of Civil Engineers, October 21; title: The Civil Engineer in Sales.

Personnel of AC Spark Plug Division's Research Laboratory who made presentations during the Science Research Career Carnival, Flint, Michigan, October 28-29, were as follows: **Edward D. DeGalan**, experimental chemist; **Helen H. Bartlett**, supervisor, ceramic research; and **Lavern M. Aurand**, experimental metallurgist.

Joseph M. Rodgers, laboratory supervisor, and **Robert J. Owens**, product engineer, Engineering Department, Delco Products Division, before Dayton, Ohio, high school juniors attending the engineering session of Career Day, November 3; title: The Eggs in My Basket.

A Typical Problem in Engineering:

Determine the Minimum Torque on an Automotive Engine Connecting Rod Bolt

When threaded fasteners are to be subjected to cyclic loading it is very important that the fatigue life of the fastener be considered. The bolts used in automotive engine connecting rods are one example of threaded fasteners subjected to such a loading condition. These bolts, which are in tension, must carry the reciprocating inertia load plus a portion of the rotating inertia load. To assure that the bolts will not fail in fatigue, they are pre-loaded to a greater tensile loading than will be encountered when the engine is in operation. The problem presented here is to determine what the minimum permissible torque on the connecting rod bolt should be to assure that the bolt will be pre-loaded to a value at least equal to or greater than the operating load.

By EDWARD C. SINTZ
and JOHN McLEOD
Cadillac Motor Car Division

Assisted by Paul H. Raker
General Motors Institute

The application of threaded fasteners has become so commonplace that quite often insufficient attention is devoted to them to obtain the most efficient fastening. The analysis of a threaded fastener of the bolt-and-nut type has many variables which the designer should consider and evaluate before releasing the fastener specifications.

Some of the more important factors to consider in the design analysis are the length of the fastener and the type of material in the bolt, nut, and parts being fastened. The physical properties of the material, particularly the tensile strength and modulus of elasticity, must be considered. Any design feature affecting friction of the nut on the bolt should be considered. A design using self-locking type nuts, which increase nut friction on the bolt, gives considerably less bolt extension for the same amount of applied torque. Finish and hardness of the abutment surfaces and the friction face of the nut have a considerable influence on the torque versus tensile load characteristics of the bolt assembly.

Perhaps the most important factor to consider in the design analysis of a bolt-type fastener is the type of loading to which the bolt will be subjected. One of the most severe applications of a bolted assembly takes place when the fastener is subjected to a cyclic load. This type of load application involves repeated loading and unloading and in some cases a change in direction of loading, which brings about a stress reversal in the bolt. In an application such as this, the designer must consider the fatigue life of the fastener in question.

Operating stress must not exceed bolt pre-load

It has been shown that the effect of cyclic loading can reduce the useful design loading of a bolt by 67 per cent in some of the most severe applications where the bolt is undergoing complete stress reversal. This can be illustrated by the familiar Goodman diagram (Fig. 1), which shows the percentage of ultimate tensile strength that can be utilized when the maximum and minimum loads in the load cycle are known.

Connecting Rod Bolts are Pre-Loaded to Prevent Fatigue Failure

In the 1959 Cadillac engine (Fig. 2) the connecting rod bolt has a self-locking nut used to retain the connecting rod cap. Two high-tensile strength bolts on each rod carry, in tension, the reciprocating inertia load plus a portion of the rotating inertia load. The design analysis for this particular component of the engine required that the load cycle carried by the bolt be evaluated so that the part would operate within the prescribed stress range for good fatigue life.

To keep the stress cycle within acceptable limits on bolted assemblies subjected to cyclic loading, it is customary to pre-load the bolts to some load which can be any value up to the yield point of the least rigid part of the assembly. Under these conditions the bolt is extended an amount proportional to the applied load and is capable of carrying loads of less magnitude than the pre-load with relatively little change in bolt extension or bolt stress. Torquing the bolt to a value which will pre-stress the bolt to a greater tensile loading than will occur during the operating cycle assures the designer that the bolt will not fail in fatigue.

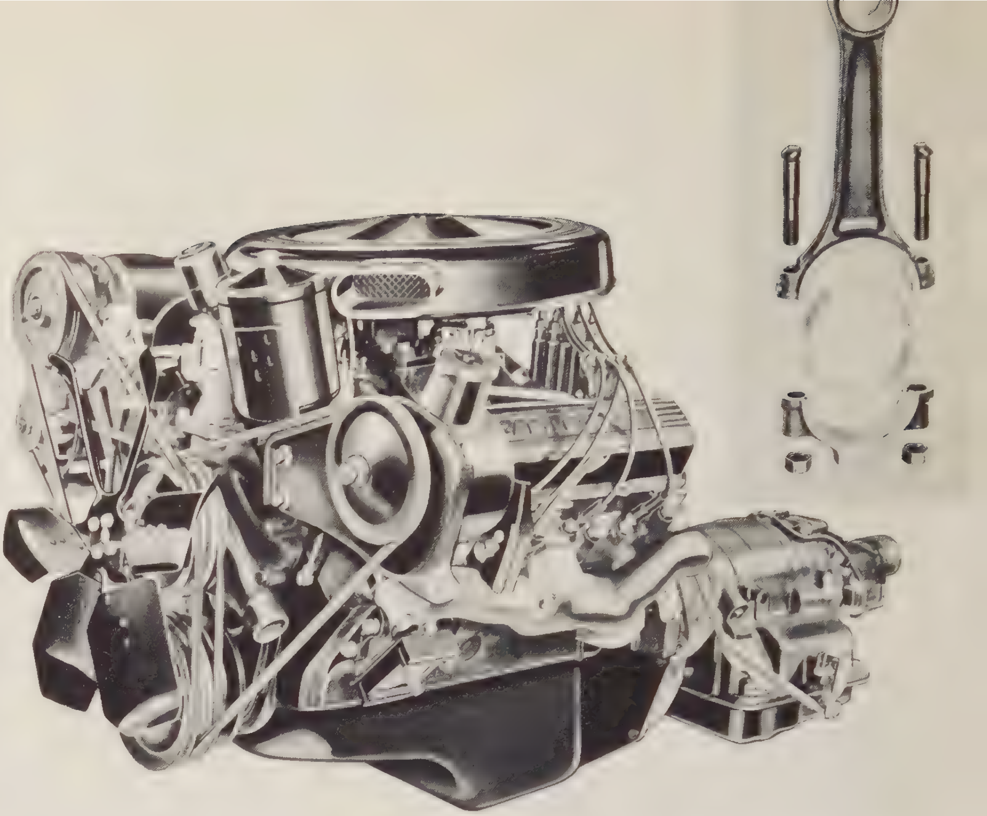


Fig. 2—In the 1959 Cadillac engine, the connecting rod bolts (inset) are pre-loaded to assure that they will not fail in fatigue.

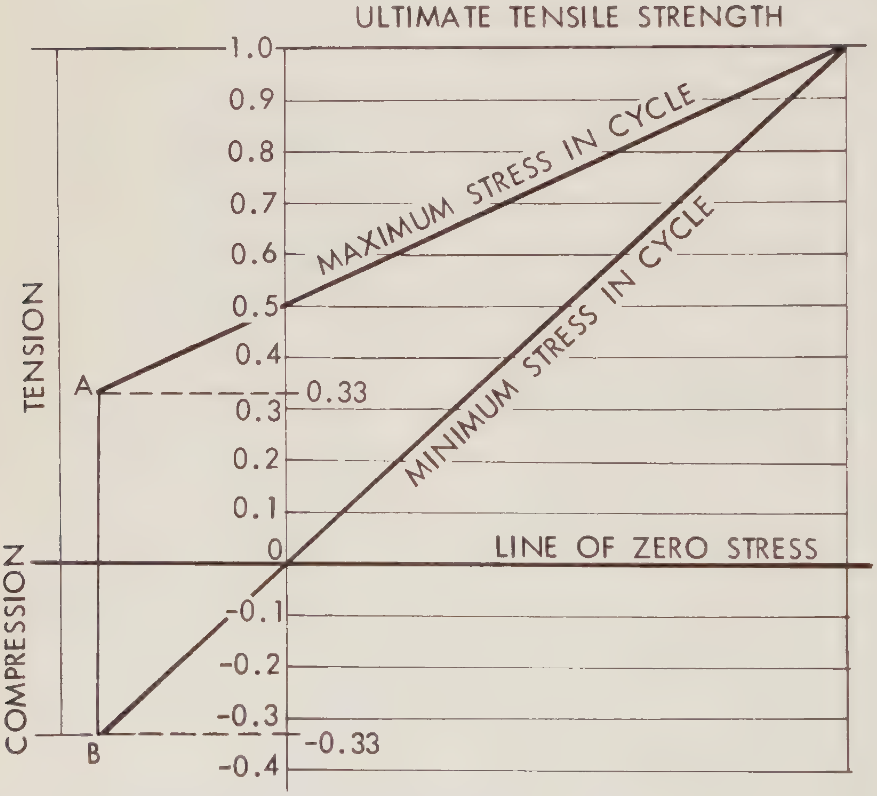


Fig. 1—The Goodman diagram, illustrated here, shows the percentage of ultimate tensile strength that can be utilized when the maximum and minimum loads in the load cycle are known. The diagram shows, for example, that when the minimum stress is zero the maximum stress for indefinite endurance should be 50 per cent of the ultimate tensile strength. When complete stress reversal takes place, as at *AB*, the plus and minus stresses are 33 per cent of the ultimate tensile strength. It has been shown that cyclic loading can reduce the useful design loading of a bolt by 67 per cent when the bolt undergoes complete stress reversal.

The reciprocating inertia loads carried by the connecting rod bolt are determined by the mass and acceleration of the piston, rings, piston pin, and upper end of the connecting rod. The acceleration of these masses is a function of the rotational speed of the crankshaft and the r/l ratio of the crank throw and connecting rod center distance (Fig. 3).

Piston pin offset affects the acceleration of the reciprocating mass, but to such a slight degree as to be disregarded in the problem to be presented. The centrifugal force of the portion of the lower-end mass of the connecting rod supported by the connecting rod bolts, however, must be considered in the problem analysis.

Problem

The problem is to determine the minimum permissible torque on the connecting rod bolt to insure that the bolt is pre-loaded to a value equal to or in excess of the maximum operating load. The torque specifications for the connecting rod bolt nuts call for 45 lb ft of torque. The minimum yield strength for the bolt material is specified at 11,500 lb.

The following information is pertinent to the solution of this problem:

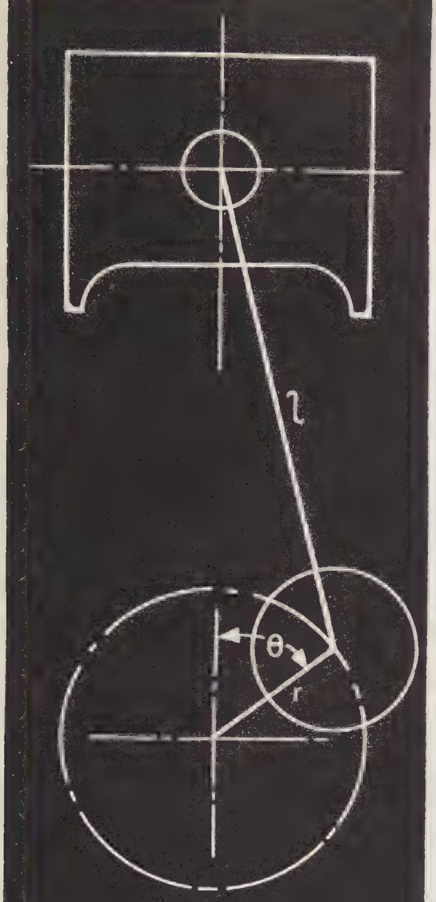


Fig. 3—The acceleration of the piston, rings, piston pin, and upper end of the connecting rod is a function of the rotational speed of the crankshaft and the r/l ratio of the crank throw radius r and connecting rod center distance l.

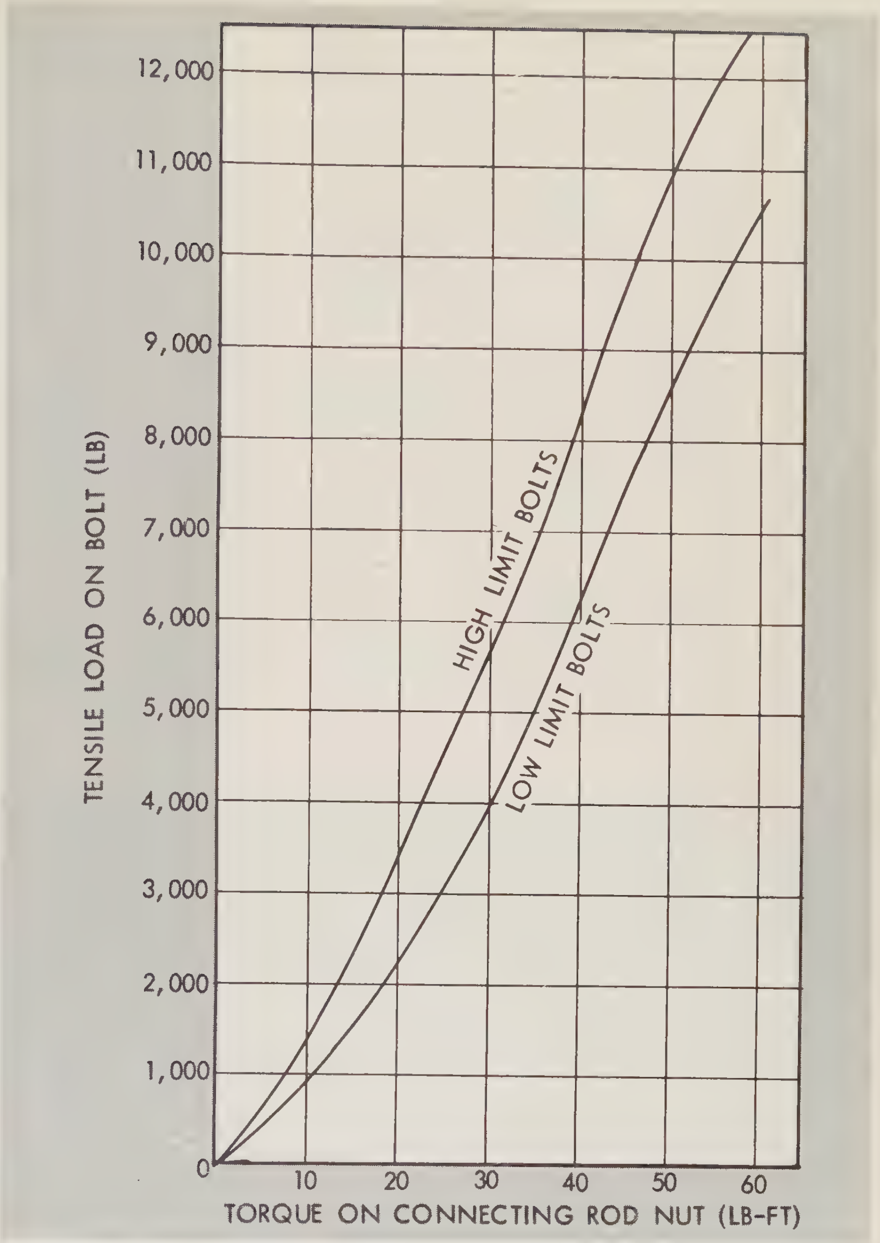


Fig. 4—Plotted here is the relationship between the torque applied to the connecting rod bolt and the actual tensile load in the bolt. The area of the curves between the high limit bolts and the low limit bolts denotes the range of tensile loading encountered when an investigation was made regarding bolt tension versus applied torque for a number of samples. This rather wide range of variation can be expected from the many variables in friction encountered in the application of threaded fasteners.

- Engine speed = n = 5,000 rpm
- Crank throw radius = r = 1.9375 in.
- Connecting rod center distance = l = 6.500 in.
- Weight of piston = 1.4100 lb
- Weight of piston rings = 0.1470 lb
- Weight of piston pin = 0.3925 lb
- Weight of upper end of connecting rod, including bolts = 0.3900 lb
- Weight of lower end of connecting rod, including bolts and cap = 1.0200 lb
- Weight of connecting rod bearing inserts (2 pieces) = 0.0900 lb
- Weight of connecting rod cap = 0.350 lb.

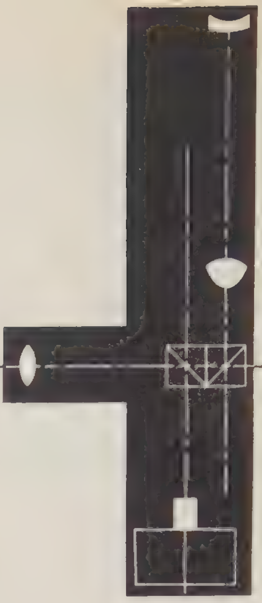
To arrive at a solution to this problem it is necessary to know the relationship between the torque applied to the connecting rod nut and the actual tensile load in the bolt (Fig. 4).

For this problem the exhaust intake portion of the conventional 4-stroke cycle can be considered the only critical period during the load cycle. Total loading can be assumed to be equally distributed between the two bolts.

The solution to the problem will appear in the April-May-June 1959 issue of the General Motors Engineering Journal.

A Typical Problem in Applied Physics:

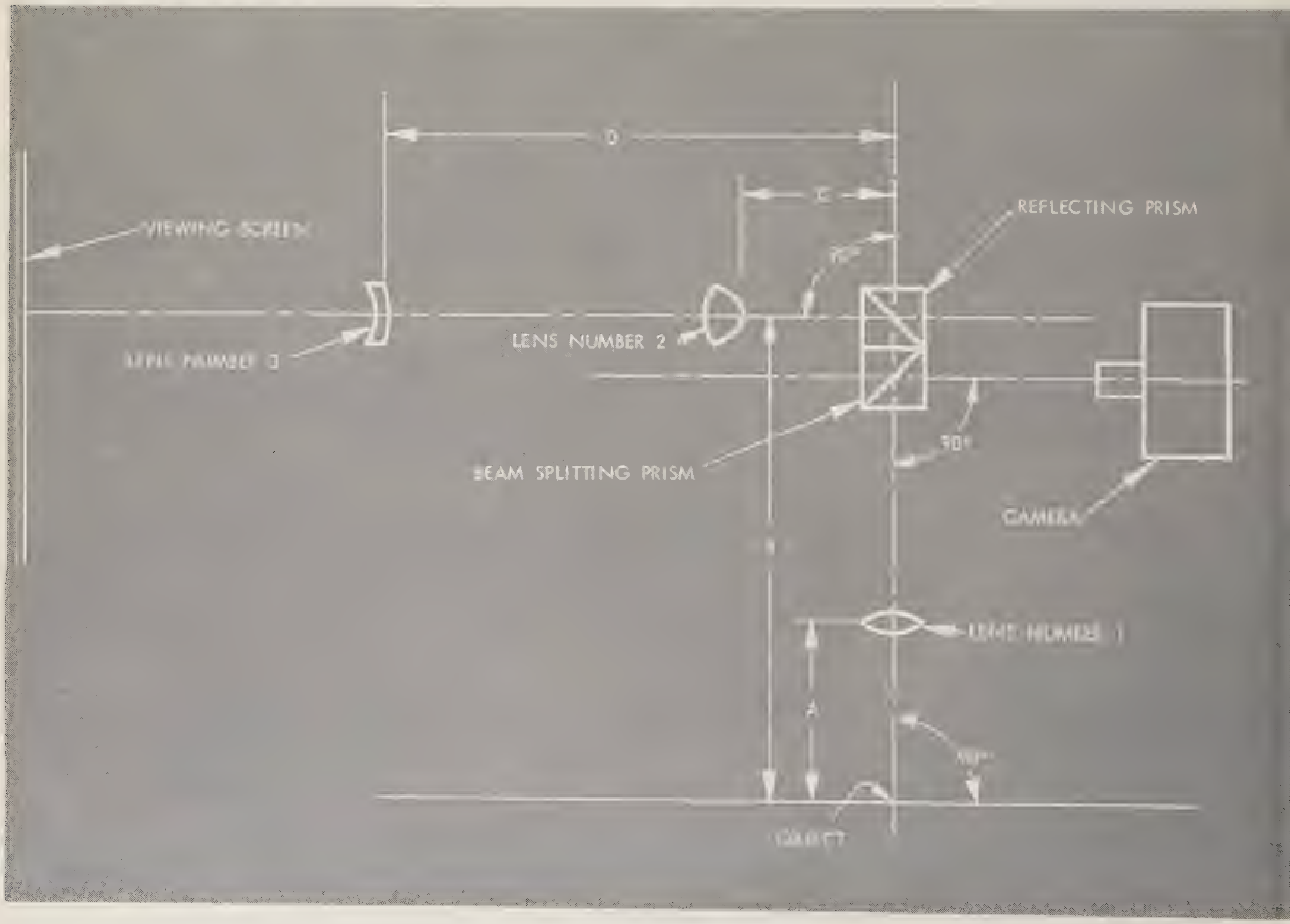
Determine the Optical Characteristics of a Beam Splitting Optical System



In most instances, the design of an optical system is based on the application of basic principles of geometrical optics. The widespread use and ever-increasing importance of optics in various industrial applications has served to create many interesting and challenging problems. The problem presented here is typical of those encountered by physicists of the GM Process Development Staff and represents but one of the many industrial applications of optics.

In recent years there has been an increased use of optics in such industrial applications as inspection, parts checking, and equipment control. With this industrial use of optics has come very interesting problems dealing with the design of optical systems and lenses.

Almost all lenses in optical systems are considered as thick lenses in the design of the system. When calculating object and image distances, therefore, the principal planes of these lenses are used. To design lenses it must be determined first what restrictions are imposed in the



By **STANLEY A. FOTTLER**
and **CARL KLIGMAN**
GM Process Development Staff

Assisted by W. Richard Struwin
General Motors Institute

Solve a problem in geometrical optics

areas of final magnification, field of view, and depth of field. Knowing this information, the following factors can be determined:

- Use of corrected lenses
- Number of lenses in the system
- Magnification of each lens
- Focal length of each lens
- Total path length.

In designing lenses, the shape factor is generally given. The shape factor, which is a number indicating the physical shape of a lens, can be determined from the radii of curvature of the lens or by calculation of the following five aberrations for minimum effect:

- Spherical aberration
- Coma
- Astigmatism
- Curvature of field
- Distortion.

These aberrations can be calculated by knowing the focal length of the lens, the magnification, and the index of refraction of the material.

Once the shape factor is determined, it is then possible to calculate the radii of curvature and the principal planes of the lens. The radii of curvature and the shape factor aid in determining the usable diameter of the lens.

When high magnifications are desired, high intensity illumination of the object is required to obtain a bright image. This can be aided by coating lenses to reduce surface reflection to a minimum and by the effect of entrance and exit pupils. Improved image quality and sharpness of focus can be obtained by properly placed stop openings.

Problem

The problem is to design an optical system (Fig. 1) which will provide a one-to-one image for the purpose of taking pictures with a movie camera and to magnify this same image for viewing purposes. The optical system is to be designed to meet the following conditions:

- Magnified image = 30 times
- Field of view = 12.7 millimeters
- Depth of field = ± 0.8 millimeters.

The optical system is to be mounted vertically, with the viewing screen and camera mounted horizontally (Fig. 1). With the required depth of field, only single element, uncorrected thick lenses are to be used.

Fig. 1—The optical system shown here must be designed to provide a one-to-one image for the purpose of taking pictures with a movie camera and then magnify this same image for viewing purposes. The optical system is mounted vertically and the camera and viewing screen are mounted horizontally. The prism system is comprised of a beam splitting prism and a reflecting prism. The focal length of lenses No. *1*, *2*, and *3* are 75 millimeters, 100 millimeters, and minus 200 millimeters, respectively. Dimensions *A*, *B*, *C*, and *D* represent distances which must be determined in order for the optical system to meet design conditions.

The following facts are known about the optical components of the system:

- Lens No. 1 has a focal length of 75 millimeters, a magnification of one, and a thickness of 9 millimeters
- The prism system is a combination of a beam splitting prism and a reflecting prism. The combined size of the prism system is 50.8 millimeters by 25.4 millimeters
- Lens No. 2 has a focal length of 100 millimeters and a magnification of 6
- Lens No. 3 has a focal length of minus 200 millimeters, a magnification of 5, and a thickness of 6 millimeters.

In the design of the optical system to meet the required conditions, the following factors must be calculated.

For Lens No. 1:

- The object and image distances
- The location of the center of the lens to the object to the nearest one millimeter (dimension *A*, Fig. 1)
- The principal planes
- The shape factor to give minimum spherical aberration and coma
- The diameter of the lens for which the deviation in focal length will not exceed 0.5 millimeters

For Lens No. 2:

- The object and image distances
- The location of the center of the lens to the object to the nearest one millimeter (dimensions *B* + *C* for Lens No. 2 and dimensions *B* + *D* for Lens No. 3)
- The principal planes
- The shape factor to give minimum spherical aberration and coma

For the complete optical system:

- The path length for the magnified image
- The path length for the camera image.

The solution to the problem will appear in the April-May-June 1959 issue of the GENERAL MOTORS ENGINEERING JOURNAL.

Solution to the Previous General Motors Institute Laboratory Problem:

Develop an Alignment Chart to Find Air-Fuel Ratios from an Orsat Analysis for the Combustion of C_8H_{18}

Faculty Members in Charge:
DONALD R. JENKINS
and FRANK N. CRALL

G.M.I. Cooperative Student:
CHARLES R. COPELAND
Allison Division

A graphical presentation of a combustion equation

The Orsat exhaust gas analysis is the method usually used to determine air-fuel ratio. To eliminate the analytical computations required to determine air-fuel ratio, graphs are available for Orsat analyses based on the combustion of a hydrocarbon fuel of specific chemical composition. While these graphs provide the ease and rapidity desired in obtaining air-fuel ratio they usually do not indicate the possibility that both carbon monoxide and oxygen can exist simultaneously in the exhaust gas. This is the solution to the problem presented in the October-November-December 1958 issue of the GENERAL MOTORS ENGINEERING JOURNAL which required the development of an air-fuel ratio alignment chart which took into consideration the fact that both CO and O_2 are present in the combustion products of C_8H_{18}.

THE OVERALL approach to the development of an alignment chart for determining air-fuel ratio for the combustion of the hydrocarbon fuel C_8H_{18} is to perform first a carbon-nitrogen balance[1] on the combustion equation of C_8H_{18}. This will provide relative weights of fuel and air which will be used as the basis for construction of the chart.

The amount of C_8H_{18} is dependent only on the amount of carbon in the exhaust gas analysis. In a like manner, the amount of air is dependent only on the amount of nitrogen in the exhaust analysis. The first step in the solution, therefore, is to determine the relative weights of fuel and air from the combustion equation of C_8H_{18}.

The combustion reaction of C_8H_{18} was assumed as follows:

$$\text{fuel} + \text{air} \rightarrow \text{combustion products}$$

$$C_8H_{18} + O_2 + N_2 \rightarrow CO_2 + CO + H_2O + O_2 + N_2 + H_2 + \text{unburned fuel.}$$

At this point in the solution, the exact molal quantities are not necessary.

An Orsat analysis gives per cent CO_2, CO, and O_2 in the dry products of combustion. The remaining percentage is assumed to be atmospheric nitrogen, which does not react in the combustion process. This gives an indication, therefore, of the amount of air in the combustion process, as follows:

$$\text{moles air} = \text{moles } N_2 + \text{moles } O_2.$$

Air was assumed to be a mechanical mixture of 79 per cent N_2 and 21 per cent O_2. Therefore,

$$\text{moles air} = \text{moles } N_2 + \frac{\text{moles } N_2}{3.76}$$

$$\text{moles air} = 1.266 \text{ moles } N_2$$

$$\text{wt air} = \text{moles air}\left(\frac{28.97 \text{ lb air}}{\text{mole air}}\right)$$

Presented here is the solution to a problem based on a typical laboratory project assigned to students enrolled in the applied thermodynamics course at General Motors Institute. Laboratory tests conducted to determine the air-fuel ratio of a spark ignition engine by means of an Orsat analysis indicated the simultaneous presence of CO and O_2 in the exhaust gas. This resulted from cylinder-to-cylinder variation in fuel distribution and imperfect mixing of the fuel within the cylinders. The test results led to the problem of whether an alignment chart could be developed which would take into consideration the fact that both CO and O_2 are present in the exhaust products of the engine. The problem allowed students to apply theoretical analysis and also practical testing procedures by obtaining an actual Orsat gas analysis.

$$\text{wt air} = 1.266 \text{ moles } N_2\left(\frac{28.97 \text{ lb air}}{\text{mole air}}\right)$$

$$\text{wt air} = 36.6(\text{moles } N_2). \qquad (1)$$

Since there must be the same number of carbon atoms on each side of the combustion equation, the following relationships hold:

$$\text{moles } C_8H_{18} = \frac{\text{moles } CO_2 + \text{moles } CO}{8} + \text{moles unburned fuel}$$

and

$$\left(\frac{\text{moles } CO_2 + \text{moles } CO}{8}\right)\left(\frac{114 \text{ lb } C_8H_{18}}{\text{mole } C_8H_{18}}\right) = \text{weight of fuel.}$$

Therefore,

$$\text{wt of fuel} = 14.25\ (\text{moles } CO_2 + \text{moles } CO). \qquad (2)$$

Since the Orsat analysis gives per cent by volume and since the mole is a volume measurement, the following substitutions may be made in equations (1) and (2):

$$\text{wt air} = 36.6\ (\%H_2)\left(\frac{\text{lb air}}{\text{100 moles of dry exhaust gas}}\right)$$

$$\text{wt } C_8H_{18} = 14.25(\%CO_2 + \%CO) + \text{moles unburned fuel}\left(\frac{\text{lb fuel}}{\text{100 moles of dry exhaust gas}}\right)$$

The preceding per cent values are from the Orsat analysis of the combustion products. If the exhaust analysis includes methane or other hydrocarbons, the equation for the weight of fuel will remain

RELATIVE WEIGHTS OF FUEL AND AIR

A + B	WEIGHT OF FUEL = 14.25 (A + B) (lb)	C	WEIGHT OF AIR = 36.6(C) (lb)	A + B	WEIGHT OF FUEL = 14.25 (A + B) (lb)	C	WEIGHT OF AIR = 36.6 (C) (lb)
10	142.50	90	3,294	16	228.00	84	3,074
11	156.75	89	3,257	17	242.25	83	3,038
12	171.00	88	3,221	18	256.50	82	3,001
13	185.25	87	3,184	19	270.75	81	2,965
14	199.50	86	3,148	20	285.00	80	2,928
15	213.75	85	3,111	21	299.25	79	2,891

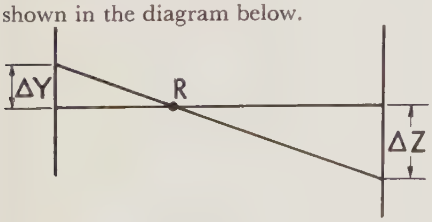
A = per cent CO_2 B = per cent CO C = per cent N_2

Table I—The calculated range of relative weights of fuel and air must be such as to provide air-fuel ratios which will extend to both the rich and lean side of the correct air-fuel ratio.

the same, with the following exception. To the per cent CO_2 and CO must be added the percentage of the hydrocarbon if it is a single carbon atom molecule. If it is a two-carbon molecule, twice the percentage must be added, and so on. In general, the amount of methane and other hydrocarbons is so low that it can be safely left out of the exhaust gas analysis.

Equations (1) and (2) are used to calculate the relative weights of fuel and air necessary for development of the alignment chart. In calculating the weights of fuel and air, the percentages of $(CO_2 + CO)$ and N_2 used in equations (1) and (2) must be such as to provide a range which will give air-fuel ratios extending to both the rich and lean side of the correct air-fuel ratio (Table I).

With the weights of fuel and air established, the final part of the solution deals with development of the alignment chart. The first step in developing the chart is to set up the two outside parallel lines, as shown in the diagram below.



A point on the middle line, or answer scale, will be determined by two sets of data having the same answer. To verify the validity of this procedure, observe the proportion which exists for two different solution lines for the same answer in the diagram. Here, R represents the answer. Geometrically then, ΔZ must always be some constant multiplied by ΔY for any two data sets with R as the answer.

Development of the alignment chart involves an equation having three variables. In general, therefore, identify the variable which, if known, will lead to an equation of the form

$$Y = KZ$$

where

K = a constant.

Then, start construction of the alignment chart with the variables Y and Z and establish the scale to be used for the answer experimentally. The method, of course, may be extended by suitable changes of the variable. The following examples will help clarify the procedure.

Example 1

Given: $R = f(Y,Z)$

Determination of R gives:

$Y = K_1(Z + K_2)$

where

K_1, K_2 = constants.

Introduce $V = (Z + K_2)$ and construct the chart using V, Y, and R. Then, label the V axis to read Z directly. It should be noted that K_1 may depend on R, but K_2 may not.

Example 2

Given: $R = f(Y,Z)$

Determination of R gives:

$Y = K_1 (\sin Z)$.

Introduce $V = \sin Z$ and proceed as in example (1). It should be noted again that K_1 may depend on R.

Those familiar with alignment chart construction will recognize that the procedure used here is somewhat simpler than the "direct" methods covered in the literature.

The alignment chart (Fig. 1) was constructed using the relative weight values for fuel and air tabulated in Table I. First, air-fuel ratios for directly opposite whole number percentages were computed from the weights of fuel and air tabulated in Table I. For example, the air-fuel ratio for 14 per cent $(CO_2 + CO)$ and 86 per cent N_2 was calculated as follows:

$$\text{air-fuel ratio} = \frac{\text{wt air}}{\text{wt fuel}}$$

$$\text{air-fuel ratio} = \frac{3{,}148 \text{ lb}}{199.5 \text{ lb}}$$

$$\text{air-fuel ratio} = 15.78 \text{ to } 1.$$

These air-fuel ratios determined straight lines between their respective percentages.

Next, the known air-fuel ratios were used to find the location of another straight, but sloping, line having the

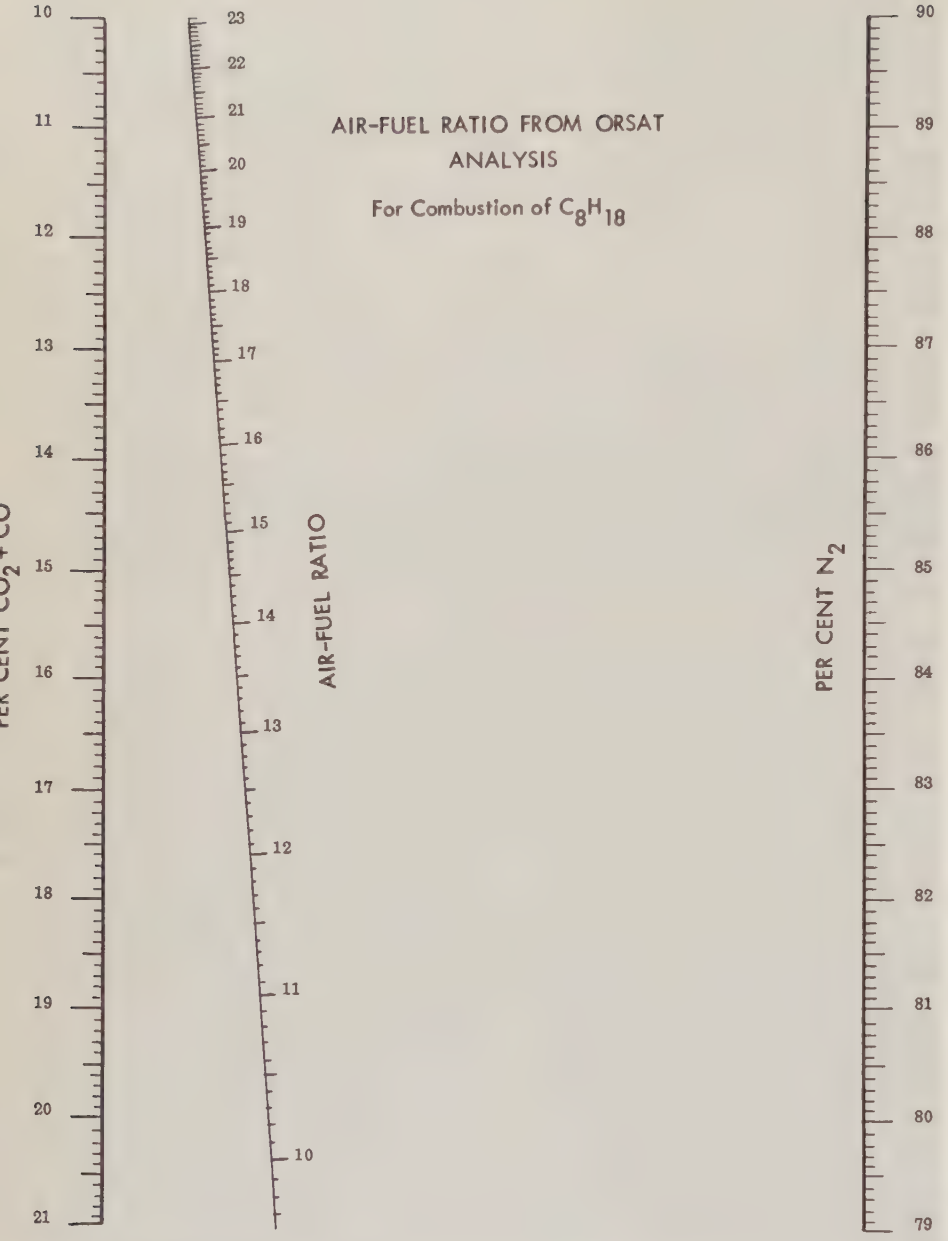


Fig. 1—The alignment chart shown here provides immediate air-fuel ratios from an Orsat analysis for the combustion of C_8H_{18}. The chart was constructed using the relative weight values of fuel and air tabulated in Table I and provides air-fuel ratios extending to both the rich and lean side of the correct air-fuel ratio. The left hand scale lists the percentage of $CO_2 + CO$. The right hand scale lists the percentage of N_2. Percentage of $N_2 = 100 -$ per cent $(CO_2 + O_2 + CO +$ other constituents, if found). Air-fuel ratio is determined by placing a straight edge between a point on the left hand scale and right hand scale and reading the desired value on the middle, or air-fuel ratio, scale.

same air-fuel ratio value. This was done by using values for per cent N_2 that did not fall on the horizontal lines. For example, the weight of fuel for an air-fuel ratio of 15 to 1 and 82 per cent N_2 was calculated as follows:

$$\text{wt fuel} = \frac{\text{wt air}}{\text{air-fuel ratio}}$$

$$\text{wt fuel} = \frac{3{,}001}{15 \text{ to } 1}$$

$$\text{wt fuel} = 200.07 \text{ lb.}$$

The weight of fuel was then converted to per cent $(CO_2 + CO)$ by interpolating between the values tabulated in Table I.

Scale divisions for the air-fuel ratio line were determined in the same manner used for determining points on the air-fuel ratio line.

To illustrate the ease and rapidity with which air-fuel ratios may be obtained with the aid of the alignment chart, consider the following Orsat exhaust gas analysis for a spark ignition engine running at full throttle:

CO_2 = 13.2 per cent
O_2 = 1.3 per cent
CO = 0.6 per cent
H_2 = 0.2 per cent.

Using the alignment chart gives, after a minor calculation is made, an air-fuel ratio of 15.75 to 1. An analytic computation based on the carbon balance method for the same Orsat analysis would give an air-fuel ratio of 15.73 to 1. Other Orsat data can be used to show correspondence of the same order, thus verifying the accuracy of the alignment chart.

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Student Contributor to the General Motors Institute Laboratory Problem

CHARLES R. COPELAND is a co-op student sponsored by Allison Division and is presently in his fourth year of study at General Motors Institute. He joined Allison Division in 1955 after completing two years of military service. His plant work assignments to date have been primarily in transmission engineering. Mr. Copeland is a member of Alpha Tau Iota, honorary society, and the G.M.I. student branch of the Society of Automotive Engineers.

Contributors to Jan.-Feb.-Mar. 1959 Issue of

GENERAL MOTORS ENGINEERING JOURNAL

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Mr. Beck joined GM in 1939 as a General Motors Institute cooperative student sponsored by Inland Manufacturing. He completed the four year course in industrial engineering in 1943, and shortly afterward entered military service which included duty as a Naval officer aboard submarines. He returned to Inland in 1946 as a correspondent in the Sales Department.

In 1947, Mr. Beck received the B.I.E. degree from General Motors Institute, and was later promoted to sales representative. He became a sales engineer in 1950. He was transferred to the Engineering Department in 1953 as a senior project engineer and was advanced to his present position in 1956. He currently is responsible for the supervision of the Product Design Department. His previous engineering projects have included product design problems involving the use of mechanical rubber extrusions and latex foam in automotive weatherstrip applications.

Mr. Beck has been co-inventor in two patents concerning design applications of mechanical rubber extrusions.

FRANK N. CRALL,

co-faculty member in charge for the typical General Motors Institute laboratory problem "Develop an Alignment Chart to Find Air-Fuel Ratios from an Orsat Analysis for the Combustion of C_8H_{18}," and the solution appearing in this issue, is an instructor in the Product Engineering Department at G.M.I. Mr. Crall teaches courses in fluid mechanics, thermodynamics, instrumentation, and engineering design, and also designs and supervises construction of laboratory equipment. He currently is developing equipment wherein a small, air-cooled air compressor is totally enclosed for complete control and measurement of its environment during testing.

Mr. Crall joined the G.M.I. faculty as an instructor in the Industrial Engineering Department after receiving the B.S.M.E. degree from Purdue University in 1947. He has taught kinematics and mechanical drawing at G.M.I., and has participated in the development of laboratory testing equipment, the development of kinematic linkage models, and the programming of student laboratory work for a computer and integration of this procedure with classroom instruction.

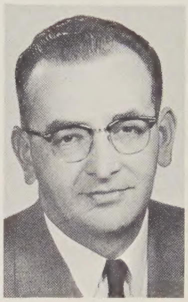
CHARLES W. CROUCH,

contributor of "Laboratory Studies of Fire Action Result in Criteria for Emergency Roof Ventilation," is engineer in charge of the Fire Protection and Prevention Department of Argonaut Realty Division, an activity of the GM Manufacturing Staff. The responsibilities of Mr. Crouch include: fire protection liaison with insurance underwriters; issuance of reports on status of compliance by GM plants to underwriters' recommendations; fire protection inspection of Argonaut-designed construction projects; consultation with plants on design; and interpretation of the GM Building Code.

Mr. Crouch joined GM in 1940 as an engineering laboratory technician with Inland Manufacturing Division. The following year he was transferred to Inland's Plant Engineering Department. In 1945 Mr. Crouch joined Argonaut Realty as a construction specification writer, and in 1948 became head of the Specification and Estimating Department. He assumed his present position in 1954.

Mr. Crouch was granted a B.S. degree in civil engineering from Northeastern University in 1934. He is a registered professional engineer in the state of Ohio and is a member of the American Society for Testing Materials and the National Fire Protection Association's Committee E5 on Fire Tests of Materials and Construction.

ROBERT J. DIKA,



contributor of "A Discussion of V-8 Engine Intake Manifold Design," is a senior designer in the Chassis Drafting Department at Pontiac Motor Division. His responsibilities include the design, layout, and checking of chassis components, particularly the engine and associated parts.

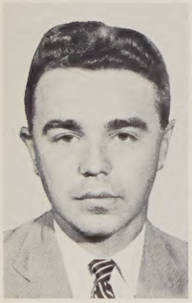
Mr. Dika joined General Motors in 1946 as a draftsman (detailer) with Pontiac Motor. Before being promoted to his present position in 1953, he held the positions of senior detailer, layout man, designer, and senior checker. Mr. Dika's previous projects have included layout and design of components of Pontiac V-8 engines, and layout, design, and installation of fuel injection induction systems in the 1957 and 1958 Pontiac passenger cars.

Mr. Dika received the B.S.M.E. degree from Lawrence Institute of Technology in 1943, where he became a member of Lambda Iota Tau honor society. He currently is taking graduate study in engineering at Wayne State University. Mr. Dika's technical affiliations include membership in the Society of Automotive Engineers.

RUSSELL V. FISHER, contributor of "A Qualitative Analysis of Automatic Control Functions," is general instrumentation supervisor of the GM Research Laboratories Electronics-Instrumentation Department. Included in his current responsibilities is the overall supervision of the design, construction, installation, modification, and servicing of approximately 16,000 Research Laboratories instruments.

Mr. Fisher is a member of the General Motors Electronics Committee and the Instrument Society of America. He has co-authored two papers which have been published in the *I.S.A. Journal.* In 1956 he won second prize for his Flexible Temperature Control System entry in the International New Ideas in Instrumentation contest, sponsored by the Instrument Society of America.

Mr. Fisher joined the Research Laboratories in 1948 as a project mechanic. He assumed his present position in 1954. He currently is completing night school work at the University of Detroit for a degree in electrical engineering.



HARRY S. FORD, JR., co-contributor of "Improved Diesel Engine Provides Increased Fuel Economy," is a senior project engineer with the Detroit Diesel Engine Division. His present responsibilities include performance design and developmental work on production Diesel engines and also turbocharging of production engines.

Mr. Ford joined Detroit Diesel in 1947 as a student engineer in the engineering laboratory after receiving a bachelor of science degree in mechanical engineering from the University of Notre Dame. Promotions since then have included detail project engineer, experimental engineer, senior experimental engineer, and his present position, which he assumed in 1955. The major portion of Mr. Ford's work since joining Detroit Diesel has been in the area of combustion and turbocharging of both production and experimental Diesel engines. Mr. Ford is a member of the Society of Automotive Engineers and serves as a member of the S.A.E. Turbosupercharger committee. He also is a member of the General Motors Diesel Combustion Committee.

ALBERT M. HEITER, contributor of "Mechanization Now Being Used in U. S. Patent Office Searches," and coordinator of this issue's "Notes About Inventions and Inventors," is a patent attorney in the Detroit Office of the Patent Section. His present responsibilities include patent application work, patent investigations, and licensing work, primarily in the automatic transmission field.

Mr. Heiter joined the General Motors Patent Section in 1946, following employment as a patent examiner with the U. S. Patent Office. He previously had served in various engineering capacities with the United States Steel Corporation, Ohio Public Service, and the National Bureau of Standards.

Mr. Heiter received a Bachelor of Mechanical Engineering degree from Rensselear Polytechnic Institute in 1937. The University of Richmond granted him the Bachelor of Laws degree in 1945. Mr. Heiter is a member of the American Patent Law Association and the Michigan Patent Law Association. He also is a member of the state Bar of Michigan and the American Bar Association.

DONALD R. JENKINS, co-faculty member in charge for the typical General Motors Institute laboratory problem "Develop an Alignment Chart to Find Air-Fuel Ratios from an Orsat Analysis for the Combustion of C_8H_{18}," and the solution appearing in this issue, is an instructor in the Product Engineering Department at G. M. I. He is instructor in charge of the thermodynamics laboratory, and teaches courses in applied thermodynamics, fluid mechanics, and instrumentation. He also is engaged in laboratory development work for instruction purposes, and has co-authored a thermodynamics laboratory and lecture manual.

Before joining the G.M.I. faculty in 1956, Mr. Jenkins taught engineering courses at the University of Maine and Lafayette College. He has had industrial experience in foundry engineering.

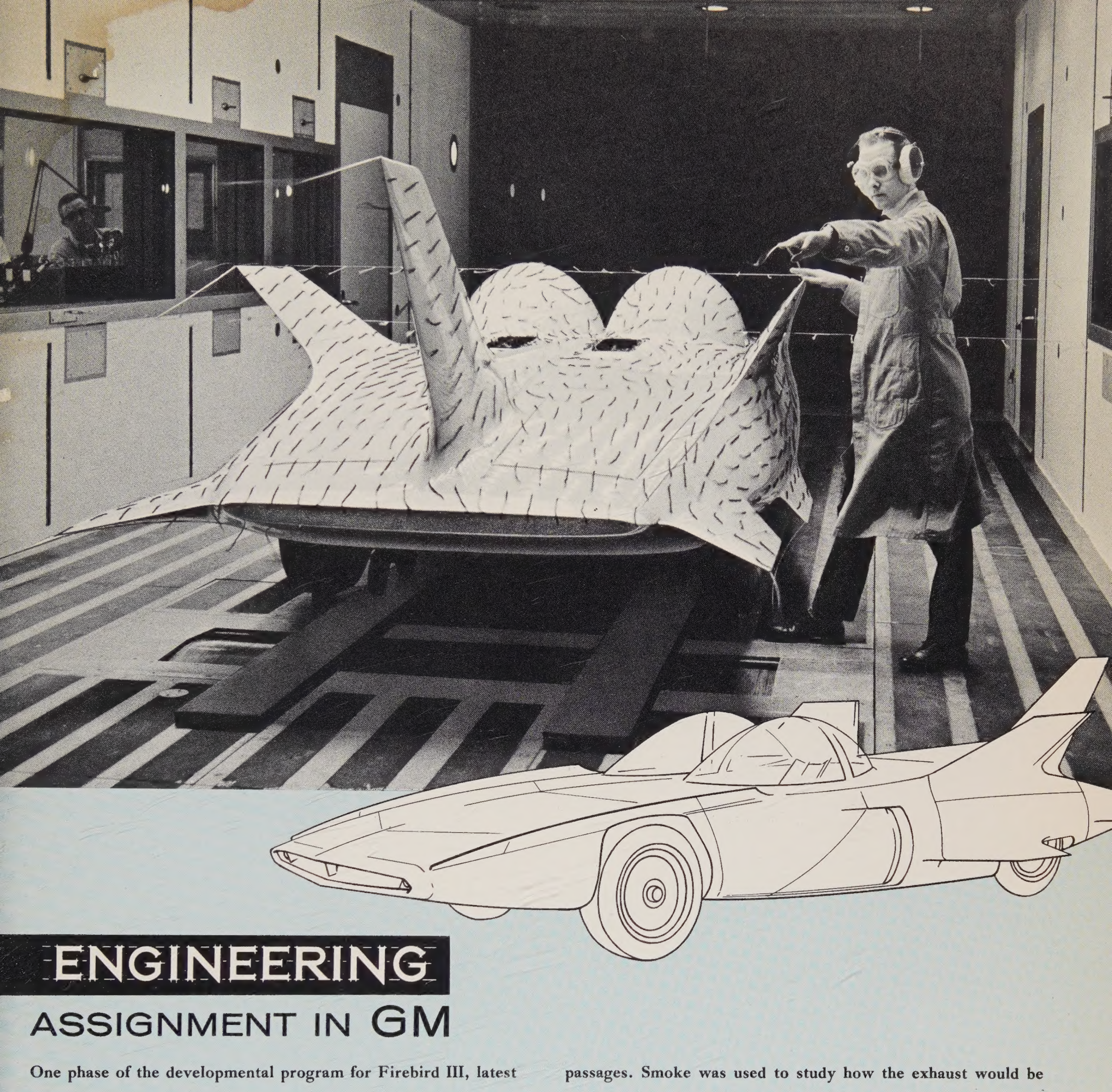
Mr. Jenkins received the B.S.M.E. degree from Rutgers University in 1946, and the M.S.M.E. degree from Lehigh University in 1951. His technical affiliations include membership in the American Society for Engineering Education, American Association of University Professors, and the Power Test Code Sub-Committee 19-E of the A.S.M.E. Mr. Jenkins is a registered professional engineer in the state of Michigan, and is an institutional representative for the Young Engineering Teachers Committee of the A.S.E.E.

JOHN J. MAY, co-contributor of "Improved Diesel Engine Provides Increased Fuel Economy," is a forward-design and development engineer with the Detroit Diesel Engine Division.

Mr. May received a B.S. degree in aeronautical engineering from New York University in 1930. He then spent the next four years with the U.S. Air Force as a pilot. From 1935 to 1938 he was an aeronautical engineering advisor and test pilot for the central government of China. After his return to this country, he joined Detroit Diesel as an experimental engineer. Promotions since that time have included senior experimental engineer, project engineer, and senior project engineer.

Previous major projects on which Mr. May has worked include combustion and injection developmental work, development of the Series 110 Diesel engine, and also developmental work in turbocharged engines. He is presently concerned with the planning, design, and development of future Diesel engines, and also the investigation of combustion systems.

Mr. May is a member of the Society of Automotive Engineers, the Smoke Meter Group and Test Technique Group of the Coordinating Research Council, and the G.M. Diesel Combustion Committee.



ENGINEERING ASSIGNMENT IN GM

One phase of the developmental program for Firebird III, latest GM experimental gas turbine powered vehicle, was devoted to conducting tests to determine the general air flow pattern around the body. These tests were conducted on a full size plaster shell of the proposed body at the Research Laboratories wind tunnel, located at the GM Technical Center.

In the accompanying photograph, Andre Treyer, research engineer with the GM Styling Staff, is shown conducting an air flow study to evaluate the aerodynamic behavior of the proposed body design. Wool tufts were positioned on the body to make the air flow pattern clearly visible. A set of electric blowers installed in the body drew air through proposed exhaust passages. Smoke was used to study how the exhaust would be dispersed into the atmosphere with the car in motion. The air studies showed that a clean flow of air took place around the body and also indicated the feasibility of using aerodynamic drag brakes at the rear of the vehicle.

Mr. Treyer was graduated from the Ecole des Mines, Paris, with an engineer's diploma M.E. in 1956. The following year he received a master of science degree in mechanical engineering from the California Institute of Technology. Shortly after receiving his master's degree, Mr. Treyer joined the General Motors Styling Staff as a research engineer in the Automotive Research Studio.

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